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Assessment of Manufacturers' Capabilities to Meet Requirements for Control of Emissions of Sulfur Dioxide Particulate Matter, and Nitrogen Oxides from Industrial Boilers

Industrial Gas Cleaning Inst, Inc, Alexandria, VA

Prepared for

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The report reviews the capabilities of manufacturers of air pollution control equipment to produce sufficient numbers of control devices for new industrial boilers with heat inputs greater than 2.9 MW thermal should regulations be promulgated. The report covers the period 1981 to 1995.

The supply of flue gas desulfurization systems will be inadequate if controls are required on small boilers. The supply of systems to control particulate matter emissions, however, should be satisfactory. The industry providing systems to treat nitrogen oxides in flue gas is poorly developed and apparently could not supply enough systems for all industrial boilers. Limited data are available about combustion modification for nitrogen oxide control, but the combustion modification industry appears abler than the flue gas treatment industry to meet a demand for more stringent control of nitrogen oxide emissions.

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ABSTRACT

The report reviews the capabilities of manufacturers of air pollution control equipment to produce sufficient numbers of systems to control sulfur dioxide, particulate matter, and nitrogen oxide emissions from new industrial boilers with heat inputs greater than 2.9 MW thermal. The report covers the period 1981 to 1995.

The supply of flue gas desulfurization systems will be inadequate if controls are required on small boilers. The supply of systems to control particulate matter emissions, however, should be satisfactory. The industry providing systems to treat nitrogen oxides in flue gas is poorly developed and apparently could not supply enough systems for all industrial boilers. Limited data are available about combustion modification for nitrogen oxide control, but the combustion modification industry appears abler than the flue gas treatment industry to meet a demand for more stringent control of nitrogen oxide emissions.

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The cooperation of the many companies that responded to this survey is gratefully acknowledged.

SECTION 1

THE PROJECT

1.1 OBJECT

The U.S. Environmental Protection Agency (EPA) is currently developing technical and economic data to support New Source Performance Standards (NSPS) for industrial boilers in accordance with Section 111 of the Clean Air Act. Selection of the best systems of emission reduction requires consideration of the availability of control equipment. The purpose of this project is to assess the capabilities of manufacturers to produce sufficient equipment to meet requirements for control of sulfur dioxide (SO_2), particulate matter, and nitrogen oxide (NO_x) emissions from industrial boilers.

1.2 EXECUTION

The Industrial Gas Cleaning Institute (IGCI), under contract to the EPA, conducted a survey of manufacturers of air pollution control equipment to determine their ability to supply: flue gas desulfurization (FGD) equipment, particulate control equipment, flue gas treatment equipment for NO_x control, and combustion modification equipment for NO_x control. Survey forms were sent to members of IGCI and to independent manufacturers of equipment to control air pollution. The survey encompassed nearly all suppliers of each of the considered types of air pollution control.

Four survey forms were devised and issued. Each form was designed to cover the following:

- Type and applicability of system.
- Pollutant removed, removal efficiency, and guarantees offered.
- Projected capability of manufacturer to produce the equipment during the periods 1981-1985, 1986-1990, and 1991-1995.
- Material requirements for construction and operation.
- Manpower requirements for construction and operation.
- Limiting item analysis.

Examples of the survey forms are presented in Appendices A through D. Unless otherwise specified, questions were asked about pollution control systems according to the heat inputs of the boilers to which they are applied. Table 1-1 lists approximate conversions which were provided as a guideline.

1.3 DATA AND ASSUMPTIONS

For aid in completing the survey, manufacturers received data on the current and projected industrial and utility boiler markets. Data on the utility market were supplied by the EPA.[1] Data on the industrial market were extracted from a report by PEDCo Environmental, Inc.;[2] projected industrial boiler capacities by fuel type (Reference 2: Table 4-5) were combined with current boiler size distribution data (Reference 2: Table 3-2) to yield the boiler population for each size range. The utility and industrial data are presented in Tables 1-2 through 1-6.

Industrial boilers accounted for 11 percent of the industrial particulate control market on average from 1974 through 1976, as shown in Table 1-7. It should not necessarily be assumed, however, that the other industries compete for the particulate control supplies reported in this survey. Many manufacturers of particulate control systems produce controls for specific industries that have not been included in the reported supply data because the controls are not suitable for use with industrial boilers.

1.4 PRESENTATION OF RESULTS

Because participation in the survey was based on the promise of anonymity, the different companies are identified only by an alphabetic identifier. These identifiers are not necessarily constant throughout the report, but are consistent among related tables. For example, Table 3-21 refers to design and installation times for fabric filters, and Table 3-22 shows startup times for fabric filters. The same letters designate the same companies in both tables. Thus, one is able to state that, for a unit larger than 73.3 MW, Company F requires 8 to 14 months to design and install a fabric filter and 0.5 to 2 months to start it up.

Many different types of FGD systems are available, and some companies manufacture more than one type. These systems are given numerical identifiers to protect the anonymity of the manufacturers. The numerical system identifiers are handled in the same way as the alphabetic company identifiers.

Comments from manufacturers are presented as received with only minor additions for clarity.

TABLE 1-1. CONVERSIONS PROVIDED WITH THE SURVEY

Heat input, MW thermal	Heat output, MW electrical	Steam output, lb/hr	Exhaust flow rate, acfm	Exhaust temperature, °F
2.9	1.0	20,000	4,400	500
7.3	2.5	50,000	10,700	400
14.7	5.0	100,000	21,500	400
29.3	10.0	200,000	35,000	350
73.3	25.0	600,000	80,000	330

TABLE 1-2. UTILITY BOILER POPULATION[1]
(No. of boilers)

Year	Coal-fired boilers	Oil- or gas-fired boilers
1985	620	220
1990	820	132
1995	1040	74

TABLE 1-3. COAL-FIRED INDUSTRIAL BOILER POPULATION[2]
(No. of boilers)

Heat input, MW thermal	1980	1985	2000
2.9 to 7.3	6,300	7,300	13,000
7.3 to 14.7	3,950	4,600	8,000
14.7 to 29.3	2,700	2,800	5,500
29.3 to 73.3	1,530	1,750	3,100
>73.3	870	1,000	1,770

TABLE 1-4. DISTILLATE-OIL-FIRED INDUSTRIAL BOILER POPULATION[2]
(No. of boilers)

Heat input, MW thermal	1980	1985	2000
2.9 to 7.3	7,850	9,400	16,900
7.3 to 14.7	5,740	6,800	12,300
14.7 to 29.3	1,680	2,100	3,700
29.3 to 73.3	840	1,050	1,850
>73.3	300	360	650

TABLE 1-5. RESIDUAL-OIL-FIRED INDUSTRIAL BOILER POPULATION[2]
(No. of boilers)

Heat input, MW thermal	1980	1985	2000
2.9 to 7.3	10,850	13,000	23,400
7.3 to 14.7	7,890	9,400	17,000
14.7 to 29.3	2,300	2,900	5,100
29.3 to 73.3	1,160	1,450	2,550
>73.3	400	500	900

TABLE 1-6. GAS-FIRED INDUSTRIAL BOILER POPULATION[2]
(No. of boilers)

Heat input, MW thermal	1980	1985	2000
2.9 to 7.3	14,300	17,300	29,500
7.3 to 14.7	9,500	11,400	19,400
14.7 to 29.3	4,000	4,900	8,400
29.3 to 73.3	1,800	2,200	3,700
>73.3	1,200	1,500	2,500

TABLE 1-7. DISTRIBUTION OF PARTICULATE CONTROL SYSTEM SALES IN 1974, 1975, AND 1976 (percentage of annual sales)

Industry	1974	1975	1976
Industrial boilers	15.9	4.4	12.6
Paper and allied products	3.6	3.5	2.8
Chemicals and allied products	4.0	3.0	3.8
Petroleum refining and related industry	2.5	6.6	1.6
Stone, clay, glass	3.9	3.3	4.4
Primary metals	16.0	12.1	15.8
Utility, federal and municipal electric power production	42.2	55.9	41.9
Unclassified	11.9	11.2	17.1

SECTION 2

FLUE GAS DESULFURIZATION SYSTEMS

2.1 INTRODUCTION

The continuing rapid development of FGD technology may affect the data in this report, especially the data for 1991-1995. Many manufacturers have indicated that market forces will be the most significant factor in the future production and development of FGD systems. If the demand exists, production will be expanded, and improved technology will be developed.

The results of the survey are tabulated below. Survey forms were issued to 20 manufacturers, 15 of whom responded. Nonresponse was due to work pressure or to recent entry into the field and consequent lack of experience to supply reliable data.

2.2 MANUFACTURERS' PRODUCTS

2.2.1 System Description

Table 2-1 lists the systems supplied by the manufacturers that responded to the survey. The sizes of most available FGD systems range from 0.3 to 1500 MW thermal, with many manufacturers having no maximum size and one manufacturer having no minimum size. In addition, the following information was provided:

- All systems are suitable for new plant and retrofit situations and for use with coal-fired boilers.
- One system is not suitable for service with oil-fired boilers.
- Very few systems are not suitable for service with gas-fired boilers.

- Nearly all systems are available only as custom-designed units, though some manufacturers indicated that the emphasis could shift to off-the-shelf units. One system is available only as an off-the-shelf unit.

- Nearly all manufacturers produce systems for which they own the license.

- Nearly all manufacturers report a satisfactory availability of raw materials for FGD system operation. One manufacturer, however, predicted a shortage of lime during the early 1980's.

- Nearly all nonregenerable systems produce byproducts that are chemically inert; however, data indicate there are noncriteria pollutants in scrubber sludge. For the systems producing a dry product, the amount of product produced is in the range of 1.5 to 4.0 lb per lb of SO_2 removed. The systems producing a liquid suspension produce approximately 8 lb of suspension (30 percent solids) per lb of SO_2 removed; most companies offer further treatment, such as dewatering, fixation, and evaporation. The great majority of the nonregenerable systems can be operated in the closed-loop mode for water.

- For all the regemerable processes, the regeneration facilities are supplied as part of the basic plant. For those processes that produce a byproduct, manufacturers have a positive attitude towards obtaining marketing contracts to dispose of the product.

2.2.2 Manpower Requirements

Tables 2-2, 2-3, and 2-4 list the manpower requirements for operation of each FGD system. Table 2-5 indicates how many manufacturers are willing to contract for operation and/or maintenance of their FGD systems and what effects such contracts, which reduce the users' manpower requirements, have upon the guarantees offered by the manufacturers.

2.3 MANUFACTURERS' GUARANTEES

Table 2-6 presents the guarantee data reported by the manufacturers of FGD systems. These data indicate the following:

- All manufacturers guarantee either SO_2 removal efficiency or SO_2 outlet emissions.

- Many manufacturers guarantee a predetermined installation cost and system availability.
- Some manufacturers guarantee particulate removal, utility consumption, and sludge quality.
- Most guarantees are qualified by design specifications, limited liability, etc.

2.4 CAPABILITIES OF MANUFACTURERS

The manufacturing capabilities of the responding companies are presented in Table 2-7. The survey form stated: "Indicate the number and total equivalent MW* of new systems, operating at the maximum efficiency previously stated, that you can design and install in the periods indicated with current and planned staff additions. Also indicate your capacity using an expanded staff or more extensive use of subcontractors. Design or installation work that has already been started is excluded from these figures."

An attempt was made in the survey to determine if lower efficiency requirements would increase manufacturing capability. None of the respondents indicated an increase in capability if the required removal efficiency was reduced. Most of the systems can be designed to remove between 95 and 100 percent SO_2. Some provide a slightly lower removal efficiency, and a few can only remove between 85 and 90 percent SO_2.

Some respondents indicated that the significant factor in their production capability is the number of systems, not the size of the systems. A few manufacturers indicated they could not supply accurate data for the question.

Table 2-8 shows that the time required for design and installation of various FGD systems varies considerably with the type of system and tends to increase with system size. Table 2-9 shows less variation in startup times than in construction schedules, indicating that most systems require similar shakedown periods.

Table 2-10 shows data on the distribution of personnel in the manufacture and construction of FGD systems. Although nearly all companies make exclusive use of in-house personnel for process design, most depend heavily on external labor for the fabrication and construction of FGD systems. Thus, the expanded production of FGD equipment may be limited by overdemand on the fabrication and construction industries. Manufacturers indicate that proportionate personnel increases are required to achieve the expanded production figures reported in Table 2-7. Approximately the same percentage increase in personnel is required as the percentage increase in production. The increased manpower figures reported by manufacturers are presented in Table 2-11.

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* Questionnaire data based on thermal MW.

2.5 LIMITING ITEM ANALYSIS

Table 2-12 is a limiting item analysis of basic critical path elements associated with the development and construction of FGD systems. The lead times in Table 2-12 cover wide ranges, and the mean values listed should be treated with some skepticism. The longer lead times indicated by some manufacturers may be realistic, although they may also be indicative of labor problems or poor choices of subcontractors. Because only one manufacturer listed the name of a subcontractor, it is not possible to analyze the demands upon specific subcontractors. For example, if all the FGD manufacturers are relying on a single pump manufacturer, the supply of FGD systems is totally dependent upon the capabilities of that pump supplier.

Table 2-13 presents key factors indicated by the manufacturers as delaying the design, construction, and startup of FGD systems. It also lists some manufacturers' suggestions to overcome delays.

TABLE 2-1. MANUFACTURERS OF FGD SYSTEMS

Company	Type of system
Apitron	Electrostatically augmented fabric filter with injection of dry pulverized quicklime[a]
Babcock and Wilcox	Limestone Lime Dry sulfur removal (various reactants available)[a]
Chiyoda International Corp.	Jet bubbling limestone/gypsum process
Combustion Equipment Associates, Inc.	Lime Lime/alkaline fly ash Sodium Double alkali Limestone
Davy Powergas	Wellman Lord[b] Modified lime solution with integrated oxidation step to produce stable gypsum
Environeering, Inc.	Lime Limestone Sodium
Envirotech/Chemico Air Pollution Control Corp.	Lime/limestone Double alkali Magnesia recycle process[b] Phosphate[b]
FMC Corporation, Environmental Equipment Division	Double alkali Sodium
Flakt, Inc.	Sodium Sodium citrate[b]
Joy Industrial Equipment Co., Western Precipitation Division	Dry scrubbing system[a]

(continued)

TABLE 2-1 (continued)

Company	Type of system
Mikropul Corp.	Lime spraydryer with fabric filter or electrostatic precipitator[a]
Neptune Airpol, Inc.	Sodium Lime/limestone Double alkali Ammonia
Peabody Process Systems, Inc.	Lime/limestone
Research Cottrell	Lime/limestone Multistage alkali
Universal Oil Products (UOP), Air Correction Div.	Lime Sodium

[a] Dry systems.

[b] Regenerative systems.

TABLE 2-2. OPERATOR TIME PER YEAR REQUIRED FOR FGD SYSTEMS (hours)

System[a]	2.9 to 7.3 MW[b]	7.3 to 14.7 MW[b]	14.7 to 29.3 MW[b]	29.3 to 73.3 MW[b]	>73.3 MW[b]
1	6,000	6,000	6,000	6,000	6,000
2	300	330	330	330	360
3					8,760[c]
4	8,000	8,000	16,000	16,000	16,000
5					25,000[d]
6					25,000[d]
7					25,000[d]
8					25,000[d]
9					25,000[d]
10	8,000	8,000	8,000	8,000	8,000
11	8,000	8,000	16,000	16,000	16,000
12	8,760	8,760	8,760	8,760	8,760
13	7,000	7,000	7,000	7,000	14,000
14	~2,200	~2,200	~4,400	~4,400	~8,760
15	4,380	4,380	4,380	8,760	8,760
16	8,760	8,760	8,760	8,760	8,760
17	2,000	2,000	4,000	6,000	6,000
18	2,190	4,380	8,760	17,520	26,280
19	2,190	4,380	8,760	17,520	26,280
20	2,190	4,380	8,760	17,520	26,280
21	2,190	4,380	8,760	17,520	26,280
22					32,000[c]
23					17,520[d]
24	2,200	2,200	2,200	2,200	2,200
25					8,760[a]
26					8,760[a]
27	8,760	8,760	8,760	8,760	8,760
28	8,760	8,760	8,760	8,760	8,760
29	7,000	7,000	7,000	7,000	14,000
30	7,000	7,000	7,000	7,000	14,000
31	7,000	7,000	7,000	7,000	14,000
32	~2,200	~2,200	~4,400	~4,400	~8,760
33	4,380	4,380	4,380	8,760	8,760
34	6,000	6,000	6,000	6,000	6,000

[a] System descriptions and manufacturers' names deliberately withheld.

[b] Thermal MW.

[c] No other date supplied, although the system is available in other size ranges.

[d] System normally supplied only in this size range.

TABLE 2-3. MAINTENANCE TIME PER YEAR REQUIRED FOR FGD SYSTEMS (hours)

System[a]	2.9 to 7.3 MW[b]	7.3 to 14.7 MW[b]	14.7 to 29.3 MW[b]	29.3 to 73.3 MW[b]	>73.3 MW[b]
1	2,000	2,000	2,000	2,000	2,000
2	300	300	330	330	360
3	c	c	c	c	c
4	7,200	7,200	7,200	7,200	12,000
5					12,480[d]
6					12,480[d]
7					12,480[d]
8					12,480[d]
9					12,480[d]
10	4,000	4,000	4,000	4,000	4,000
11	10,000	10,000	20,000	20,000	20,000
12	0	4,380	8,760	8,760	8,760
13	1,750	1,750	1,750	1,750	3,500
14	∿4,400	∿4,400	∿8,760	∿8,760	∿8,760
15	8,760	8,760	8,760	17,520	17,520
16	8,760	8,760	8,760	17,520	17,520
17	2,000	2,000	4,000	6,000	12,000
18	876	1,051	2,190	4,380	8,760
19	876	1,051	2,190	4,380	8,760
20	876	1,051	2,190	4,380	8,760
21	876	1,051	2,190	4,380	8,760
22					16,000[e]
23					15,000[d]
24	1,500	1,500	1,500	1,500	1,500
25	c	c	c	c	c
26	c	c	c	c	c
27	0	4,380	8,760	8,760	8,760
28	0	4,380	8,760	8,760	8,760
29	1,750	1,750	1,750	1,750	3,500
30	1,750	1,750	1,750	1,750	3,500
31	1,750	1,750	1,750	1,750	3,500
32	∿4,400	∿4,400	∿8,760	∿8,760	∿8,760
33	8,760	8,760	8,760	17,520	17,520
34	2,000	2,000	2,000	2,000	2,000

[a] System descriptions and manufacturers' names deliberately withheld.

[b] Thermal MW.

[c] No data received.

[d] System normally supplied only in this size range.

[e] No other data supplied, although the system is available in other size ranges.

TABLE 2-4. SUPERVISOR TIME PER YEAR REQUIRED FOR FGD SYSTEM (hours)

System[a]	2.9 to 7.3 MW[b]	7.3 to 14.7 MW[b]	14.7 to 29.3 MW[b]	29.3 to 73.3 MW[b]	>73.3 MW[b]
1	2,000	2,000	2,000	2,000	2,000
2	40	40	40	40	40
3					8,760[c]
4	2,000	2,000	2,000	2,000	2,000
5					2,080[d]
6					2,080[d]
7					2,080[d]
8					2,080[d]
9					2,080[d]
10	2,000	2,000	2,000	2,000	2,000
11	2,000	2,000	4,000	4,000	4,000
12	0	0	0	0	8,760
13	1,750	1,750	1,750	1,750	3,500
14	0	0	0	0	0
15	2,920	2,920	2,920	2,920	2,920
16	8,760	8,760	8,760	8,760	8,760
17	0	0	0	0	0
18	219	438	1,051	2,190	4,380
19	219	438	1,051	2,190	4,380
20	219	438	1,051	2,190	4,380
21	219	438	1,051	2,190	4,380
22					11,000[c]
23					2,190[c]
24	0	0	0	0	0
25					8,760[c]
26					8,760[c]
27	0	0	0	0	8,760
28	0	0	0	0	8,760
29	1,750	1,750	1,750	1,750	3,500
30	1,750	1,750	1,750	1,750	3,500
31	1,750	1,750	1,750	1,750	3,500
32	0	0	0	0	0
33	2,920	2,920	2,920	2,920	2,920
34	2,000	2,000	2,000	2,000	2,000

[a] System descriptions and manufacturers' names deliberately withheld.

[b] Thermal MW.

[c] No other data supplied, although the system is available in other size ranges.

[d] System normally supplied only in this size range.

TABLE 2-5. FGD SYSTEMS WHOSE MANUFACTURERS ARE WILLING TO CONTRACT FOR OPERATION, MAINTENANCE, OR SUPERVISION AND EFFECTS OF CONTRACTS ON GUARANTEES

System[a]	Effect on guarantees
4	Manufacturer willing only to recommend an experienced operation and maintenance company
5	More stringent availability guarantees
6	More stringent availability guarantees
7	More stringent availability guarantees
8	More stringent availability guarantees
9	More stringent availability guarantees
10	Generally improved long-term guarantees
11	Generally improved long-term guarantees
13	Generally improved guarantees concerning chemical and utility consumption and availability
14	No comment about effect on guarantees
15	Improved performance guarantees
17	Higher availability guarantees
23	Guaranteed maximum operational and/or maintenance cost if advisor is at plant
24	Guaranteed maximum operational and/or maintenance cost if advisor is at plant
29	Generally improved guarantees concerning chemical and utility consumption and availability
30	Generally improved guarantees concerning chemical and utility consumption and availability
31	Generally improved guarantees concerning chemical and utility consumption and availability
32	No comment about effect on guarantees
33	Improved performance guarantees

[a] System descriptions and manufacturers' names deliberately withheld.

TABLE 2-6. FGD SYSTEM GUARANTEES

System[a]	SO_2 removal efficiency	Predetermined installation cost	Availability	Other
1	Yes--for specified inlet concentration and reactant quality	Yes--for specified time period with escalation included	Yes--if maintained and operated per instructions	Yes--no increase in particulate emissions
2	Yes--negotiated	Yes--same guarantees offered as those from subcontractors	Yes--negotiated	Yes--particulate removal negotiated
3	Yes--to meet emission requirements	No	No	Yes--outlet particulate concentration not to exceed inlet concentration; draft loss: power consumption; sludge production
4	Yes--90 to 95 percent removal	Yes--lump sum price	Yes--90 percent	Yes--particulate removal from 75 to 95 percent; power consumption; limestone consumption; gypsum quality
5	Yes--if assembled and operated in accordance with specifications	Yes--if assembled and operated in accordance with specifications	Yes--if assembled and operated in accordance with specifications	Yes--particulate removal, if assembled and operated in accordance with specifications; will modify system to meet guarantees, but costs not to exceed total profit
6	Yes--if assembled and operated in accordance with specifications	Yes--if assembled and operated in accordance with specifications	Yes--if assembled and operated in accordance with specifications	Yes--particulate removal, if assembled and operated in accordance with specifications; will modify system to meet guarantees, but costs not to exceed total profit

(continued)

TABLE 2-6 (continued)

System[a]	SO_2 removal efficiency	Predetermined installation cost	Availability	Other
7	Yes--if assembled and operated in accordance with specifications	Yes--if assembled and operated in accordance with specifications	Yes--if assembled and operated in accordance with specifications	Yes--particulate removal, if assembled and operated in accordance with specifications; will modify system to meet guarantees, but costs not to exceed total profit
8	Yes--if assembled and operated in accordance with specifications	Yes--if assembled and operated in accordance with specifications	Yes--if assembled and operated in accordance with specifications	Yes--particulate removal, if assembled and operated in accordance with specifications; will modify system to meet guarantees, but costs not to exceed total profit
9	Yes--if assembled and operated in accordance with specifications	Yes--if assembled and operated in accordance with specifications	Yes--if assembled and operated in accordance with specifications	Yes--particulate removal, if assembled and operated in accordance with specifications; will modify system to meet guarantees, but costs not to exceed total profit
10	Yes--negotiated	Yes--negotiated	Yes--negotiated	Yes--raw material and utility consumption negotiated
11	Yes--negotiated	Yes--negotiated	Yes--negotiated	Yes--particulate removal negotiated, raw material and utility consumption negotiated
12	Yes	Yes	Yes--but not to exceed 95 percent	Yes--particulate removal

(continued)

TABLE 2-6 (continued)

System[a]	SO_2 removal efficiency	Predetermined installation cost	Availability	Other
13	Yes--unlimited liability	Yes--lump sum plus escalation; cost plus fixed fee	Yes	Yes--particulate removal, unlimited liability; utilities, sludge disposal properties, raw material consumption; liquidated damages basis
14	Yes--Equipment revamped or replaced without limitation	Yes--escalation acaccording to Bureau of Labor Statistics (BLS) indices	Yes--as part of performance tests	Yes--particulate removal equipment revamped or replaced without limitation; chemicals and power (excess consumption paid for 2 yr)
15	Yes	Yes	Yes	Yes--particulate removal
16	Yes--limited liability	Yes--with escalation and limited liability	Yes--limited liability	Yes--particulate removal; pressure drop; reagent and power consumption; limited liability
17	Yes--to meet codes	Yes--progress payments	Yes--over 90 percent	Yes--particulate removal to meet codes
18	Yes--minimum inlet SO_2 concentration, if operated and maintained per instructions	No	Yes--negotiated	Yes--particulate removal for minimum inlet concentration, if operated and maintained per instructions
19	Yes--minimum inlet SO_2 concentration, if operated and maintained per instructions	No	Yes--negotiated	Yes--particulate removal for minimum inlet concentration, if operated and maintained per instructions
20	Yes--96 percent; operation per instructions	Yes--firm price	No	Yes--particulate removal up to 98 percent, if operated per instructions

(continued)

TABLE 2-6 (continued)

System[a]	SO_2 removal efficiency	Predetermined installation cost	Availability	Other
21	Yes--minimum inlet concentration; operate and maintain per instructions	No	Yes--negotiated	Yes--particulate removal for minimum inlet concentrations, if operated and maintained per instructions
22	Yes--operation and maintenance per instructions and within design specifications	Yes--subject to escalation	No	Yes--power, stoichiometry sludge produced, reactant consumption, if operation and maintenance per instructions and within design specifications
23	Yes--guaranteed emissions	Yes--guaranteed price	Yes--if operations advisor at site	Yes--particulate removal; other items guaranteed to meet customer's requirements
24	Yes--guaranteed emissions	Yes--guaranteed price	Yes--if operations advisor at site	Yes--particulate removal; other items guaranteed to meet customer's requirements
25	Yes--to meet emission requirements	No	No	Yes--particulate not to exceed inlet; draft loss; power consumption; sludge production
26	Yes--to meet emission requirements	No	No	Yes--particulate not to exceed inlet; draft loss; power consumption; sludge production
27	Yes	Yes	Yes--but not to exceed 95 percent	Yes--particulate removal
28	Yes	Yes	Yes--but not to exceed 95 percent	Yes--particulate removal

(continued)

TABLE 2-6 (continued)

System[a]	SO_2 removal efficiency	Predetermined installation cost	Availability	Other
29	Yes--unlimited liability	Yes--lump sum plus escalation; cost plus fixed fee	Yes	Yes--particulate removal, unlimited liability; utilities, sludge disposal properties, raw material consumption; liquidated damages basis
30	Yes--unlimited liability	Yes--lump sum plus escalation; cost plus fixed fee	Yes	Yes--particulate removal, unlimited liability; utilities, sludge disposal properties, raw material consumption; liquidated damages basis
31	Yes--unlimited liability	Yes--lump sum plus escalation; cost plus fixed fee	Yes	Yes--particulate removal, unlimited liability; utilities, sludge disposal properties, raw material consumption; liquidated damages basis
32	Yes--equipment revamped or replaced without limitation	Yes--escalation according to BLS indices	Yes--as part of performance tests	Yes--particulate, revamp or replace equipment without limitation; chemicals and power, will pay for 2 years' excess consumption
33	Yes	Yes	Yes	Yes--particulate removal
34	Yes--inlet concentration specified; reactant quality	Yes--specified time period; escalation	Yes--maintenance and operation per instructions	Yes--no increase in particulates

[a] System descriptions and manufacturers' names deliberately withheld.

TABLE 2-7. PRODUCTION CAPABILITY OF FGD SYSTEM MANUFACTURERS

	1981-1985		1986-1990		1991-1995	
	Present staff	Expanded staff	Present staff	Expanded staff	Present staff	Expanded staff
Design capability						
Number	413	854	678	1,244	883	1,549
Capacity, MW equivalent[a]	50,050	90,350	66,500	119,225	80,700	152,850
Installation capability						
Number	274	453	357	564	413	679
Capacity, MW equivalent[a]	43,135	70,340	49,965	87,800	55,375	106,575

[a] Thermal MW.

TABLE 2-8. TIME FOR DESIGN AND INSTALLATION OF FGD SYSTEMS (months)

Company[a]	2.9 to 7.3 MW[b]		7.3 to 14.7 MW[b]		14.7 to 29.3 MW[b]		29.3 to 73.3 MW[b]		>73.3 MW[b]	
	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range
A	NR[c]	NR	NR	NR	NR	NR	NR	NR	NR	24-30
B[d]	18	16-20	18	16-20	18	16-20	18	16-20	18	16-20
B[d]	24	22-26	24	22-26	24	22-26	24	22-26	24	22-26
C	10	8-12	12	10-14	12	10-14	12	10-14	20	16-24
D	12	9-15	12	9-15	18	15-21	18	15-21	24	18-30
E	18	16-20	18	16-20	20	18-22	20	18-22	24	20-28
F	6	4-7	8	6-10	10	8-14	12	8-16	12	8-16
G	12	10-14	12	10-14	13	11-15	14	12-16	14	12-16
H	9-12	9-12	9-12	9-12	9-12	9-12	12-15	12-15	12-15	12-15
I	10	8-12	12	10-12	14	12-18	18	16-20	20	18-24
J	NR	NR	NR	NR	NR	NR	NR	NR	24	22-26
K	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
L	12	10-16	12	10-18	14	12-20	16	12-22	18	18-24
M	5	4-6	5	4-6	6	5-8	6	5-8	8	7-10
N	NR	NR	NR	NR	NR	NR	NR	NR	33	26-42
O	15	12-20	15	12-20	18	15-24	18	15-24	24	20-32

[a] Company names deliberately withheld.

[b] Thermal MW.

[c] NR = No response.

[d] This company supplies two products with different leadtimes.

TABLE 2-9. TIME FOR STARTUP OF FGD SYSTEMS
(months)

Company[a]	2.9 to 7.3 MW[b]		7.3 to 14.7 MW[b]		14.7 to 29.3 MW[b]		29.3 to 73.3 MW[b]		>73.3 MW[b]	
	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range
A	NR[c]	NR	NR	NR	NR	NR	NR	NR	NR	3-6
B[d]	2	1-3	2	1-3	2	1-3	2	1-3	2	1-3
B[d]	2	2-3	2	2-3	2	2-3	2	2-3	2	2-3
C	3	2-4	4	3-5	4	3-5	4	3-5	6	5-7
D	1	0.5-3	1	0.5-3	1	0.5-3	1	0.5-3	1	0.5-3
E	2	1-3	2	1-3	2	1-3	2	1-3	2	1-3
F	1	1-2	1	1-2	2	1-2	2	1-2	2	1-2
G	1	1-2	1	1-2	1	1-2	1	1-2	1	1-2
H	2	1-3	2	1-3	2	1-3	2	1-3	2	1-3
I	0.5	0.3-0.7	0.75	0.5-1	1	0.5-1.5	1.5	1-2	2	1.5-2.5
J	NR	NR	NR	NR	NR	NR	NR	NR	2	1-3
K	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
L	0.5	0.5-1	0.5	0.5-1	0.5	0.5-1	0.5	0.5-2	0.5	0.5-2
M	2	1-3	2	1-3	2	1-3	2	1-3	2	1-3
N	NR	NR	NR	NR	NR	NR	NR	NR	3	2-5
O	1	0.5-1.5	1	0.5-1.5	1	0.5-1.5	1	0.5-1.5	2	1-3

[a] Company names deliberately withheld.

[b] Thermal MW.

[c] NR = no response.

[d] This company supplies two products with different startup times.

TABLE 2-10. LABOR DISTRIBUTION IN THE MANUFACTURE AND CONSTRUCTION OF FGD SYSTEMS[a] (percentages)

Company[b]	Process design		Detailed design		Equipment fabrication								System installation			
					Scrubber vessel/tanks		Fans/pumps		Sludge disposal system		Unspecified		Supervision		Craft	
	In[c]	Out[d]	In[c]	Out[d]	In[c]	Out[d]	In[c]	Out[d]	In[c]	Out[d]	In[c]	Out[d]	In[c]	Out[d]	In[c]	Out[d]
A	100	0	80-90	10-20	0	100	0	100	0	100			100	0	0	100
B	100	0	100	0	0	100	0	100	NA[e]	NA			100	0	0	100
C	20	0	30	0							0	100	20	0	30	0
D	100	0	100	0	0	100	0	100	0	100			25	75	0	100
E	100	0	80	20							10	90	100	0	0	100
F	100	0	80	20							0	100	75	25	0	100
G	100	0	80	20	50	50	0	100	NA	NA			100	0	0	100
H	90	10	15	85							10	90	ND[f]	ND	ND	ND
I	100	0	100	0	0	100	0	100	0	100			0	100	0	100
J	100	0	100	0							0	100	0	100	0	100
K	100	0	100	0							0	100	10	90	0	100
L	100	0	100	0	50	50	10	90	20	80			90	10	0	100
M	5	5	25	5							65	20		10	5	60
N	100	0	100	0	100	0	0	100	0	100			100	0	ND	ND
O	100	0	60	40	0	100	0	100	0	100			20	80	0	100

[a] Values listed as given by manufacturers; some values may not add up to 100 %.

[b] Company names deliberately withheld.

[c] Work done in-house.

[d] Work contracted out.

[e] Not applicable.

[f] Required data not received.

TABLE 2-11. ADDITIONAL ANNUAL LABOR TO MEET EXPANDED FGD PRODUCTION DURING 1981-1985 (man-years)

Company[a]	Design	Engineering	Craft[b]	Administration
A	35	20	0	10
B	12	10	120	38
C	NR[c]	NR	NR	NR
D	40	40	100	20
E	3	3	0	4
F	72	48	0	120
G	3	3	6	3
H	96	36	0	18
I	30	50	0	10
J	3	2	0	1
K	NR	NR	NR	NR
L	40	20	10	20
M	10	4	0	1
N	50	25	0	10
O	2	2	0.5	0.5

[a] Manufacturers' names deliberately withheld.

[b] Because most craft labor is supplied by external contractors, the total increase in craft labor demand will be far greater than indicated in this table.

[c] NR = No response.

TABLE 2-12. LIMITING ITEM ANALYSIS FOR FGD SYSTEMS

	Leadtime, months		Critical path item, %[a]		Delay frequency, %[a]			Supplier, %[a]		
	Range	Mean	Yes	No	High	Average	Low	External	In-house	Both
Process design	1-12	3.4	53	7	7	7	47	0	40	0
Detailed engineering design	1-14	6.9	60	7	7	33	27	0	33	7
Equipment fabrication										
Structural steel	2-17	6	33	27	0	27	27	20	13	0
Scrubber vessel tanks	3-14	7.3	47	13	7	40	7	33	0	7
Fans	4-18	9.8	53	13	33	27	7	47	0	0
Pumps	2-18	7.6	7	47	7	33	13	40	7	0
Instrumentation	2-20	8	33	27	13	33	7	27	0	0
Motors	2-18	8.8	20	47	13	33	20	47	0	0
Piping	2-20	6.8	33	27	13	27	13	33	0	0
Equipment installation	2-30	11.5	60	13	40	27	0	20	7	20
Reactant procurement (e.g., limestone)	0.5-4	1.8	0	60	7	27	20	27	0	0

[a] Values indicate the percentage of the manufacturers listed in Table 2-1 that responded to each question.

TABLE 2-13. KEY FACTORS DELAYING FGD SYSTEMS AND CORRECTIVE ACTIONS RECOMMENDED BY MANUFACTURERS

Company[a]	Delay cause	Corrective action
A	Design changes and lack of communication, slowness in obtaining a decision	Reduce items listed as much as possible
B	Design: insufficient in-house personnel Construction: inability to hire required craft labor Startup: inavailability of qualified personnel	Industry: order systems promptly; approve drawings and specifications promptly; pre-commit long-delivery items when necessary Government: expedite approvals from regulatory agencies
C	Client's approval of drawings, modifications and changes, errors in engineering and/or fabrication	Approve drawings quickly; eliminate delay in issuing building permits
D	No special equipment required; all major components are standard proven products	None required
E	No comment	No comment
F	Specification and design changes; lack of coordination with A/E when systems are not turnkey	NR[b]
G	General equipment arrangement and disposal scheme	Educate regulatory agencies and end-users, and reduce uncertainty about what is and is not possible or required
H	Slow client approval of P&ID and general arrangement drawings; late delivery of equipment	Follow critical path schedule
I	Shortage of local skilled labor, adverse weather conditions, uncertainty in regulation requirements	Promulgate revised NSPS as soon as possible; allow reasonable time for design, installation, and startup

(continued)

TABLE 2-13 (continued)

Company[a]	Delay cause	Corrective action
J	Design: poor scope of definition, owner changes Construction: poor productivitiy, labor unrest Startup: operating problems with source of flue gas, equipment failure or failure to meet specifications	Develop need and/or interest
K	Equipment delivery, construction delay (inclement weather, strikes, etc.)	A period of 24 to 30 months to complete a project appears reasonable
L	Slow delivery of rotating equipment, field fabrication of scrubber	NR
M	Delay in vendor and raw material shipment	NR
N	None	None required
O	Manpower shortage, poor coordination of labor	NR

[a] Company names deliberately withheld.

[b] NR = No response.

SECTION 3

PARTICULATE CONTROL SYSTEMS

3.1 INTRODUCTION

The technology of particulate control is well established, although improvements are still being made. Essentially, four types of equipment are used for controlling particulate emissions from industrial boilers: electrostatic precipitators (ESP's), fabric filters, wet scrubbers, and mechanical collectors. The ESP's and fabric filters have the greatest potential for emission reduction. Although wet scrubbers can achieve low emission rates, high operating costs (due mainly to the large energy requirement of the fans) make such scrubbers unattractive economically. Mechanical collectors are only applicable if regulations allow high particulate emissions, because the maximum collection efficiency is about 95 percent.

A survey form concerning particulate control systems (see Appendix B) was developed and issued to 36 manufacturers. Of these, 17 manufactured ESP's, 19 made fabric filters, 15 supplied wet scrubbers, and 11 produced mechanical collectors. Six other ESP manufacturers, 13 other fabric filter manufacturers, 8 other wet scrubber manufacturers, and 10 other mechanical collector manufacturers were asked to participate in the survey, but all declined by telephone before the survey forms were issued. Of these, about 50 percent were members of the IGCI. Those who declined to participate in the survey (before and after the survey form was issued) did so either because of work pressure or because their products were not directed towards the industrial boiler market. The responses of those manufacturers who did complete the survey form are discussed in the following subsections.

3.2 ELECTROSTATIC PRECIPITATORS

3.2.1 Manufacturers' Products

3.2.1.1 System Description--

Table 3-1 lists the manufacturers that produce ESP's for the industrial boiler market and responded to the survey. They supplied the following information:

- All systems are suitable for use with coal-fired boilers. Most systems are suitable for use with oil-fired boilers.
- All systems are suitable for both new and retrofit situations.
- All systems are custom-designed for the specific installation.
- Nearly all manufacturers produce systems based on their own designs.
- The ESP's are available to handle flue gas from boilers with heat inputs of 3 MW thermal and more. Some manufacturers specify no top size.

3.2.1.2 Manpower Requirements--

Tables 3-2, 3-3, and 3-4 list the manpower requirements for operation, maintenance, and supervision of each ESP. Table 3-5 indicates how many manufacturers are willing to contract for operation and/or maintenance of their ESP's and what effects such contracts, which reduce the users' manpower requirements, will have upon the guarantees offered by the manufacturers. As can be seen from Table 3-5, five of the eight manufacturers surveyed will contract for operation and/or maintenance, but only one will improve the guarantees offered.

3.2.2 Manufacturers' Guarantees

Table 3-6 lists the data about guarantees reported by the manufacturers. The major points are:

- All manufacturers guarantee either total outlet particulate loading or particulate removal efficiency, if operating design conditions are met.

- All manufacturers guarantee a predetermined installation cost for specified conditions.
- Only 50 percent of the manufacturers guarantee availability.
- Opacity, maxiumum pressure drop, and maximum power consumption may also be guaranteed.

3.2.3 Capabilities of Manufacturers

Table 3-7 presents the reported production capability for ESP's. Two interesting comments were also received:

- One manufacturer believed that production would fall in the period 1991-1995, because of market saturation.
- Two manufacturers indicated that their production capacity would increase if the percentage particulate removal required were lowered. One manufacturer reported that his production would increase by 20 percent with a 5 percent decrease in removal efficiency and by 50 percent with a 10 percent decrease in removal efficiency. The other manufacturer indicated that his production capacity would increase by about 15 percent with a 5 to 10 percent decrease in removal efficiency. Thus, for a 5 percent reduction in removal efficiency, the total capability of design systems reported in Table 3-7 would increase by 9.1 percent during the period 1981-1985; for a 10 percent decrease in removal efficiency, the capability would increase by 14.4 percent. The production capability increases because an ESP providing a lower particulate removal efficiency requires less plate area and is smaller.

Table 3-8 shows the data reported about the time required for design and installation of ESP's. The time varies slightly among manufacturers, but generally tends to increase as the size of the system increases.

Table 3-9 shows the data reported about the time required for startup of ESP's. All of the startup periods are short, and nearly all are less than two months.

Table 3-10 shows the labor distribution in the manufacture and construction of electrostatic precipitators. The data reported indicate, as expected, a very heavy dependence upon contractors for the craftwork in the construction of ESP's. Table 3-11 presents the data reported about the additional manpower required for the expanded production shown in Table 3-7.

3.2.4 Limiting Item Analysis

Table 3-12 is a limiting item analysis for ESP systems. Except for equipment installation, the estimated leadtimes are not greater than 8 months and vary by no more than 4 months for each item. One manufacturer reported that because of the present limited number of manufacturers of ESP plates and discharge electrodes, supplies could fall short of demand.

Some of the data in Tables 3-10 and 3-12 may be wrong. Companies B and D supplied information used in developing Table 3-10 that contradicts the information from them used in developing Table 3-12. Thus some of the data reported in this section are uncertain.

Table 3-13 lists key factors indicated by the manufacturers as delaying the design, construction, and startup of ESP's. The manufacturers' suggestions to overcome delays are also presented.

3.3 FABRIC FILTERS

3.3.1 Manufacturers' Products

3.3.1.1 System Description--

Table 3-14 lists the manufacturers that produce fabric filters for the industrial boiler market and responded to the survey. They supplied the following information:

- All systems are suitable for use with coal-fired boilers, but only about half of the systems are suitable for use with oil-fired boilers.* One system requires an "additive system" with oil-fired boilers.
- All systems are suitable for use with both new and existing industrial boilers.

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*Fabric filters have seldom been used with oil-fired boilers. Blinding of filter media can easily occur.

- All systems are available as custom-designed units, and many are also available as off-the-shelf units.
- All manufacturers produce equipment for which they own the license.
- Fabric filters are available for use on boilers with heat inputs from 1 to 2500 MW thermal.

3.3.1.2 Manpower Requirements--

Tables 3-15, 3-16, and 3-17 list the manpower requirements for operation, maintenance, and supervision of fabric filters. Because the data reported span three orders of magnitude for virtually identical systems, some manufacturers were asked to verify their original answers, but none modified the data supplied. Bag replacement, which must be carried out every 2 or 3 years, may account for some of the discrepancies among data. If the replacement of one bag takes roughly 30 minutes, the replacement of 10,000 bags in a system could take as long as 5,000 hours.[3] Some manufacturers have included bag replacement time in their manpower data, whereas others have not. This difference, however, does not seem to explain completely the wide discrepancies.

Table 3-18 lists how many manufacturers are willing to contract for operation and/or maintenance of fabric filters. The table also indicates what effects such contracts, which reduce the users' manpower requirements, will have upon guarantees.

3.3.2 Manufacturers' Guarantees

Table 3-19 lists the guarantee data reported by the manufacturers. The major points are:

- All manufacturers guarantee either a removal efficiency or a maximum mass outlet loading, which is usually conditional on operation and maintenance per instructions.
- Nearly all manufacturers offer a predetermined installation price.
- Seventy percent of manufacturers guarantee availability.

- Pressure drop, power consumption, opacity, and bag life may also be guaranteed.

3.3.3 Capabilities of Manufacturers

Table 3-20 presents the reported production capability for fabric filters that operate at the maximum achievable removal efficiency (99.9+ percent). Manufacturers were also asked whether lowering the removal efficiency would affect their capability. The responses indicated that production would not increase. One manufacturer reported that lowering removal efficiency would reduce production because wet scrubbers would become competitive and the demand for fabric filters would decline. For 10 percent reduction in efficiency the manufacturer estimated a 50 percent reduction in production, which would reduce the combined capability of all the manufacturers by 3 percent.

Table 3-21 shows the data reported about the time required for design and installation of fabric filters. Table 3-22 lists the data reported about the time required for startup of fabric filters.

Table 3-23 gives the labor distribution in the manufacture and construction of fabric filters. As with the other systems, manufacturers depend very heavily upon contract labor for field fabrication and construction. Table 3-24 presents the data reported about the additional labor required to achieve the expanded production shown in Table 3-20.

3.3.4 Limiting Item Analysis

Table 3-25 presents a limiting item analysis for fabric filters. With the exception of equipment installation, the estimated leadtimes are not greater than 8 months and vary by no more than 6.5 months for each item.

As with the data reported about ESP's, some data reported about fabric filters appear uncertain. Company I supplied information used in developing Table 3-23 that contradicts the information from it used in developing Table 3-25.

Table 3-26 lists key factors indicated by the manufacturers as delaying the design, construction, and startup of fabric filters. The table also includes manufacturers' suggestions to overcome the delays.

3.4 MECHANICAL COLLECTORS

Because very few manufacturers supplied data about mechanical collectors, the following discussion may only represent the responding manufacturers, not the whole mechanical collector industry.

3.4.1 Manufacturers' Products

3.4.1.1 System Description--

Table 3-27 lists the three manufacturers that produce mechanical collectors for the industrial boiler market and who responded to the survey. They supplied the following information:

- All systems are suitable for use with both coal- and oil-fired boilers.
- All systems are suitable for both new and retrofit situations.
- All systems are available as both custom-designed and off-the-shelf units.
- All manufacturers produce systems for which they own the license.
- Mechanical collectors are available for boilers with heat inputs from less than 1 MW thermal to 1200 MW thermal. One manufacturer did not respond to the question about boiler size.
- The maximum removal efficiency reported was 97.5 percent and depended upon system design and inlet particulate qualities.

3.4.1.2 Manpower Requirements--

The manufacturers reported that no operators or supervisors are necessary for operation of a mechanical collector. One manufacturer estimated that 208 man-hours per year are necessary for maintenance of any size of mechanical collector. Another manufacturer reported "Annual inspection only--replacement of worn parts," for maintenance requirements and did not estimate the man-hours. The third manufacturer did not answer the question about manpower requirements.

Two manufacturers were willing to provide periodic maintenance inspection during outages. The other manufacturer was willing to provide a field service engineer to assist the customers with problems. None of these services were reported as having any effect upon the guarantees offered.

3.4.2 Manufacturers' Guarantees

The guarantees offered by the three manufacturers are listed in Table 3-28. They do not appear to be as extensive as the guarantees offered by ESP and fabric filter manufacturers.

3.4.3 Capabilities of Manufacturers

Table 3-29 lists the reported production capabilities for mechanical collectors. The manufacturers indicated that production would not increase if the removal efficiency were lowered.

One manufacturer reported that the average time from order to shipment is 24 to 26 weeks, with startup time no longer than 2 to 3 days. Another manufacturer reported that design takes 1 to 4 weeks, and fabrication and shipment takes 6 to 20 weeks depending on size. The third manufacturer did not respond to this question.

The labor distribution for the manufacture of mechanical collectors is shown in Table 3-30.

Table 3-31 presents data on the additional labor required to achieve the expanded production shown in Table 3-29.

3.4.4 Limiting Item Analysis

No manufacturer of mechanical collectors responded to Question 22 of the particulate control survey.

Table 3-32 lists the key factors indicated by the manufacturers as delaying the design, construction and startup of mechanical collectors. No corrective actions were suggested.

3.5 WET SCRUBBERS

Because very few manufacturers supplied data on wet scrubbers, the following discussion may only represent the responding manufacturers, not the whole wet scrubber industry.

3.5.1 Manufacturers' Products

3.5.1.1 System Description--

Envirotech/Chemico Air Pollution Control Corp. and Research Cottrell make venturi scrubber systems suitable for use with industrial boilers.

- Both systems are suitable for use with coal- and oil-fired boilers.
- Both systems are suitable for use in retrofit and new situations.
- One manufacturer produces only custom-designed systems; the other manufacturer produces both custom-designed and off-the-shelf systems.
- Both manufacturers produce systems for which they own the license.
- Maximum particulate removal efficiency is 99.9+ percent.
- There is no size limitation.

3.5.1.2 Manpower Requirements--

Table 3-33 presents data on the total annual man-hours required for operation, maintenance, and supervision of a wet scrubber. The responses of the two companies differ significantly.

Table 3-34 lists the manufacturers willing to contract for operation and/or maintenance of wet scrubbers. The table also indicates what effects such contracts, which reduce the users' manpower requirements, will have upon the guarantees.

3.5.2 Manufacturers' Guarantees

Table 3-35 lists the guarantee data reported by the manufacturers. The guarantees seem fairly comprehensive.

3.5.3 Capabilities of Manufacturers

Table 3-36 presents the reported production capability for wet scrubbers that operate at the maximum possible removal efficiency. Manufacturers indicated that their capability would not be increased if the required removal efficiency were lowered.

Table 3-37 indicates the time required for design, installation, and startup of the systems.

Table 3-38 presents the distribution of labor in the manufacture and construction of wet scrubbers. As with other systems, the manufacturers depend heavily upon external labor for equipment fabrication and installation.

Table 3-39 lists the data reported about the additional manpower required to achieve the expanded production shown in Table 3-36.

3.5.4 Limiting Item Analysis

Neither manufacturer answered Question 22 of the particulate control survey.

Table 3-40 lists the key factors indicated by the manufacturers as delaying the design, construction, and startup of wet scrubbers. The manufacturers' suggestions to overcome delays are also reported.

TABLE 3-1. MANUFACTURERS OF ELECTROSTATIC PRECIPITATORS

Company
C-E Walther
Environmental Elements Corp.
Envirotech Corporation, Buell Emission Control Division
Joy Industrial Equipment Company, Western Precipitator Division
Peabody Process Systems, Inc.
Research Cottrell, Inc.
United McGill Corporation
Universal Oil Products, Air Correction Division

TABLE 3-2. OPERATOR HOURS PER YEAR REQUIRED FOR ELECTROSTATIC PRECIPITATORS

Company[a]	2.9 to 7.3 MW[b]	7.3 to 14.7 MW[b]	14.7 to 29.3 MW[b]	29.3 to 73.3 MW[b]	>73.3 MW[b]
A	NA[c]	NA	166	166	166
B	1825	1825	1825	1825	1825
C	1750	1750	1750	1750	1750
D	NA	NA	NR[d]	0	0
E	0	0	0	0	0
F	NR	NR	NR	NR	NR
G	NA	NA	330	365	400
H	NR	NR	NR	NR	NR

[a] Manufacturers' names deliberately withheld.

[b] Thermal MW.

[c] NA = Not applicable. Manufacturer does not produce systems in this size range.

[d] NR = No response.

TABLE 3-3. MAINTENANCE HOURS PER YEAR REQUIRED FOR ELECTROSTATIC PRECIPITATORS

Company[a]	2.9 to 7.3 MW[b]	7.3 to 14.7 MW[b]	14.7 to 29.3 MW[b]	29.3 to 73.3 MW[b]	>73.3 MW[b]
A	NA[c]	NA	320	320	320
B	300	400	600	900	1200
C	1750	1750	1750	1750	1750
D	NA	NA	NR[d]	4000	8000
E	8760	8760	8760	8760	8760
F	NR	NR	NR	NR	NR
G	NA	NA	250	275	300
H	NR	NR	NR	NR	NR

[a] Manufacturers' names deliberately withheld.

[b] Thermal MW.

[c] NA - Not applicable. Manufacturer does not produce systems in this size range.

[d] NR = No response.

TABLE 3-4. SUPERVISOR HOURS PER YEAR REQUIRED FOR ELECTROSTATIC PRECIPITATORS

Company[a]	2.9 to 7.3 MW[b]	7.3 to 14.7 MW[b]	14.7 to 29.3 MW[b]	29.3 to 73.3 MW[b]	>73.3 MW[b]
A	NA[c]	NA	26	26	26
B	0	0	0	0	0
C	438	438	438	438	438
D	NA	NA	NR[d]	0	0
E	0	0	0	0	0
F	NR	NR	NR	NR	NR
G	NA	NA	40	50	60
H	NR	NR	NR	NR	NR

[a] Manufacturers' names deliberately withheld.

[b] Thermal MW.

[c] NA = Not applicable. Manufacturer does not produce systems in this size range.

[d] NR = No response.

TABLE 3-5. MANUFACTURERS WILLING TO CONTRACT FOR OPERATION AND/OR MAINTENANCE OF ELECTROSTATIC PRECIPITATORS AND EFFECT OF CONTRACTS ON GUARANTEES

Company[a]	Effect on guarantees
A	None
B	None
C	None
E	Generally no effect
H	Guaranteed availability

[a] Manufacturers' names deliberately withheld.

TABLE 3-6. ELECTROSTATIC PRECIPITATOR GUARANTEES

Company[a]	Particulate removal	Predetermined installation cost	Availability	Other
A	Yes--specified fuel	Yes--escalation clause	Yes--12 months at design conditions	Yes--opacity with specified stack diameter and fuel for particulate only
B	Yes--efficiency, based on minimum inlet particulate concentration and maximum volume flow	Yes--but preliminary engineering funds required for providing firm price of turnkey installation	No--because cannot control preventive maintenance	
C	Yes	Yes	No	
D	Yes--efficiency, based on fuel analysis and ash composition, correct operation, etc.	Yes--clearly defined scope and timing	Yes--based upon proper maintenance and periodic service inspection	
E	Yes--efficiency, with option for minimum outlet grain loading	Yes--subject to escalation according to government material index and field labor wage rates	Yes--continuous operation in most cases	
F	Yes--efficiency as required based on specified inlet grain loading to precipitator and coal and/or ash analysis	Yes--subject to adjustment on labor rate changes	No	Yes--opacity 20 percent, pressure drop

(continued)

TABLE 3-6 (continued)

Company[a]	Particulate removal	Predetermined installation cost	Availability	Other
G	Yes--based on operation design conditions	Yes--limited to specific installation contacts	No--normally dependent on maintenance by others	Yes--maximum pressure drop and maximum power consumption, both subject to operation at design conditions
H	Yes--based on coal ash composition and flue gas conditions	Yes--with escalation	Yes--based on contract for maintenance supervisor	Yes--pressure loss, opacity, electrical power consumption

[a] Maunfacturers' names deliberately withheld.

TABLE 3-7. PRODUCTION CAPABILITY OF ELECTROSTATIC PRECIPITATOR MANUFACTURERS[a]

	1981-1985		1986-1990		1991-1995	
	Present staff	Expanded staff	Present staff	Expanded staff	Present staff	Expanded staff
Design capability						
Number	270	416	308	520	321	614
Capacity, MW equivalent[b]	20,560	31,520	26,951	41,320	27,620	43,920
Installation capability						
Number	238	378	270	473	290	578
Capacity, MW equivalent[b]	13,745	20,780	17.561	26,980	18,465	29,930

[a] Represents the responses of seven manufacturers.

[b] Thermal MW.

TABLE 3-8. TIME FOR DESIGN AND INSTALLATION OF ELECTROSTATIC PRECIPITATORS
(months)

Company[a]	2.9 to 7.3 MW[b]		7.3 to 14.7 MW[b]		14.7 to 29.3 MW[b]		29.3 to 73.3 MW[b]		>73.3 MW[b]	
	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range
A	NA[c]	NA	NA	NA	16	12-20	18	14-22	20	16-24
B	9	8-12	10	9-12	11	10-13	12	11-14	13	12-15
C	12	10-14	13	10-15	14	12-15	15	13-16	16	14-18
D	NA	NA	NA	NA	NR[d]	NR	20	16-24	24	20-28
E	9	7-14	9	7-14	9	7-14	16	10-22	22	16-28
F	NA	NA	NA	NA	NR	NR	NR	NR	12	11-14
G	NA	NA	NA	NA	18	16-20	9	16-22	24	22-26
H	9	8-12	9	8-12	12	10-14	18	14-20	24	20-26

[a] Manufacturers' names deliberately withheld.

[b] Thermal MW.

[c] NA = Not applicable. Manufacturer does not produce systems in this size range.

[d] NR = No response.

TABLE 3-9. TIME FOR STARTUP
OF ELECTROSTATIC PRECIPITATORS
(months)

Company[a]	2.9 to 7.3 MW[b]		7.3 to 14.7 MW[b]		14.7 to 29.3 MW[b]		29.3 to 73.3 MW[b]		>73.3 MW[b]	
	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range
A	NA[c]	NA	NA	NA	0.4	0.2-0.6	0.5	0.3-0.7	0.7	0.4-1.0
B	0.5	0-1	1	0.5-1.5	1	0.5-1.5	1	0.5-1.5	1	0.5-1.5
C	0.2	0.2-0.5	0.4	0.2-0.6	0.4	0.4-0.8	0.7	0.6-1.0	1	0.7-1.5
D	NA	NA	NA	NA	NR[d]	NR	1	0.5-3	2	1-4
E	1	1-2	1	1-2	1	1-2	1	1-2	1	1-2
F	NA	NA	NA	NA	NR	NR	NR	NR	1	0.5-2
G	NA	NA	NA	NA	1	0-2	1	0-2	2	1-3
H	0.2	0.2-0.5	0.2	0.2-0.5	0.2	0.2-0.5	0.5	0.5-0.8	0.6	0.5-0.8

[a] Manufacturers' names deliberately withheld.

[b] Thermal MW.

[c] NA = Not applicable. Manufacturer does not produce systems in this size range.

[d] NR = No response.

TABLE 3-10. LABOR DISTRIBUTION IN THE MANUFACTURE AND CONSTRUCTION OF ELECTROSTATIC PRECIPITATORS (percentages)

							System installation			
	Process design		Detailed design		Equipment fabrication		Supervision		Craft	
Company[a]	In[b]	Out[c]	In[b]	Out[c]	In[b]	Out[c]	In[b]	Out[c]	In[b]	Out[c]
A	100	0	100	0	15	85	100	0	NR[d]	NR
B[e]	100	0	95	5	70	30	100	0	10	90
C	100	0	100	0	60	40	100	0	0	100
D[e]	100	0	75	25	0	100	75	25	0	100
E	100	0	70	30	95	5	100	0	10	90
F	100	0	100	0	100	0	100	0	0	100
G	100	0	90	10	60	40	50	50	0	100
H	100	0	100	0	85	15	100	0	10	90

[a] Manufacturers' names deliberately withheld.

[b] Work done in-house.

[c] Work contracted out.

[d] NR = No response.

[e] See Section 3.2.4.

TABLE 3-11. INCREASED MANPOWER REQUIRED TO MEET EXPANDED ELECTROSTATIC PRECIPITATOR PRODUCTION (man-years/year)

Company[a]	Design	Engineering	Craft[b]	Administration
A	15	5	50	0
B	2	4	8	2
C	NR[c]	NR	NR	NR
D	10	7	0	3
E	2	25	8	8
F	24	10	0	37
G	100	55	400	65
H	NR	NR	NR	NR

[a] Manufacturers' names deliberately withheld.

[b] Because most craft labor is supplied by external contractors, the total increase in craft labor demand will be greater than indicated in this table.

[c] NR = No response.

TABLE 3-12. LIMITING ITEM ANALYSIS FOR ELECTROSTATIC PRECIPITATORS

	Leadtime, months		Critical path item, %[a]		Delay frequency, %[a]			Supplier, %[a]		
	Range	Average	Yes	No	High	Average	Low	External	Internal	Both
Process design	1-3	1.8	43	43	0	57	43	0	86	0
Detailed engineering design	2-5	3	71	14	14	71	14	0	71	14
Equipment fabrication										
Unspecified	4-6	5.25	28	14	0	43	14	14	14	0
Shell or casing	2-6	4	28	0	0	14	14	28	0	0
Collecting electrodes	4	4	14	0	0		14	14	0	0
Discharge electrodes	4	4	14	0	0		14	0	14	0
Transformer/ rectifier sets	6-8	6.8	28	28	0	14	14	28	14	0
Control panel	2-3	2.5		14	0					
Rappers	4	4	14	0	0		14	14	0	0
Ductwork	3	3	14	0	0		14	14	0	0
Equipment installation	4-12	7.6	57	28	0	78	7	28	14	0

[a] Values indicate the percentage of the manufacturers listed in Table 3-1 that responded to each question.

TABLE 3-13. KEY FACTORS DELAYING ELECTROSTATIC PRECIPITATORS AND CORRECTIVE ACTIONS RECOMMENDED BY MANUFACTURERS

Company[a]	Delay cause	Corrective action
A	Specification addendums, late A/E approval of drawings, late A/E fabrication inspection, late erection, late commissioning, erratic scheduling of materials	Government should not delay issuance of building and operating permits
B	Design: additional equipment other than ESP, such as supporting structure, outlets and inlets; consultants acting between customers and ESP manufacturer and delaying drawing approval; work load of ESP manufacturers; personnel; mistakes of all parties involved; interferences of ESP layout with other equipment requiring costly and time-consuming delays; lead-time on electrical equipment	No comment
	Construction: strikes, labor productivity, unqualified erectors, shipping delays and damages, poor storage facilities, poor site access, fabrication errors, construction interferences, weather	
	Startup: equipment failures other than ESP	
C	No comment	No comment

(continued)

TABLE 3-13 (continued)

Company[a]	Delay cause	Corrective action
D	Design: changes in scope of work, drawing approvals and other approvals extended, specific problems requiring technical solutions Construction: material and equipment delivered late, field parts misfitted, lack of sufficient craft labor, lack of sufficient erection equipment Startup: construction incomplete or unacceptable, other systems components not ready	A consistent project coordination effort will overcome many delays; more realistic project planning and scheduling are basically required
E	Lack of comprehensive environmental protection legislation, inability of industry to analyze and plan for future pollution control requirements, regarding statute enforcements, conflict of government agencies leading to end-user foot dragging	All delays are caused by the government; no one is going to exercise initiative until the U.S. Government gets its act under control
F	Buyer indecision and delay in release of capital funds; buyer withholds funds until last minute, then attempts to impose unreasonable time schedule on vendor	None
G	Resolution of customer design requirements; scheduling engineering, drafting, fabrication and installation (seasonal and manpower considerations); coordination of startup with entire installation	Firmly establish requirements as early as possible; maintain close liaison for realistic scheduling
H	Late return of approval drawings, changes in scope of work to be done, changes by customer in time scheduling when design and fabrication are started	Project management and quality assurance programs decrease delaying time

[a] Manufacturers' names deliberately withheld.

TABLE 3-14. MANUFACTURERS OF FABRIC FILTERS

Company	Description
Apitron	Electrostatically augmented
C-E Air Preheater	Reverse air
Environeering, Inc.	Reverse air Pulse jet
Environmental Elements Corp.	
Envirotech Corp., Buell Emission Control Division	Reverse air/shaker option Reverse air Pulse jet
Fuller Company	Fiberglass bags with reverse air Fiberglass bags with pulse jet
Griffin Environmental Co., Inc.	Continuous-duty, high-temperature design; reverse air with optional shaker assist
Industrial Clean Air, Inc.	
Joy Industrial Equipment Co., Western Precipitation Division	
Research-Cottrell, Inc.	Reverse air/shaker Pulse jet

TABLE 3-15. OPERATOR MAN-HOURS PER YEAR REQUIRED FOR FABRIC FILTERS

Company[a]	2.9 to 7.3 MW[b]	7.3 to 14.7 MW[b]	14.7 to 29.3 MW[b]	29.3 to 73.3 MW[b]	>73.3 MW[b]
A	110	120	130	140	160
B	546	546	1092	2730	5460
C	12	12	12	20	>40
D	NR[c]	NR	NR	NR	NR
E	200	400	600	800	1600
F	5760	5760	5760	NA[d]	NA
G	8760	8760	8760	8760	8760
H	0	0	0	0	0
I	NR	NR	NR	NR	NR
J	NR	NR	NR	NR	NR

[a] Manufacturers' names deliberately withheld.

[b] Thermal MW.

[c] NR = No response.

[d] NA = Not applicable. Manufacturer does not produce systems in this size range.

TABLE 3-16. MAINTENANCE MAN-HOURS PER YEAR REQUIRED FOR FABRIC FILTERS

Company[a]	2.9 to 7.3 MW[b]	7.3 to 14.7 MW[b]	14.7 to 29.3 MW[b]	29.3 to 73.3 MW[b]	>73.3 MW[b]
A	110	120	130	140	160
B	273	273	546	1,638	2,730
C	10	10	10	20	>40
D	NR[c]	NR	NR	NR	NR
E	100	200	400	800	1,600
F	1,920	3,840	3,840	NA[d]	NA
G	8,760	8,760	8,760	17,520	17,520
H	8,760	8,760	8,760	8,760	8,760
I	NR	NR	NR	NR	NR
J	NR	NR	NR	NR	NR

[a] Manufacturers' names deliberately withheld.

[b] Thermal MW.

[c] NR = No response.

[d] NA = Not applicable. Manufacturer does not produce systems in this size range.

TABLE 3-17. SUPERVISOR HOURS PER YEAR REQUIRED FOR FABRIC FILTERS

Company[a]	2.9 to 7.3 MW[b]	7.3 to 14.7 MW[b]	14.7 to 29.3 MW[b]	29.3 to 73.3 MW[b]	>73.3 MW[b]
A	0	0	0	0	0
B	0	0	0	0	546
C	0	0	0	0	0
D	NR[c]	NR	NR	NR	NR
E	20	20	40	40	80
F	1,920	1,920	1,920	NA[d]	NA
G	0	0	8,760	8,760	8,760
H	0	0	0	0	0
I	NR	NR	NR	NR	NR
J	NR	NR	NR	NR	NR

[a] Manufacturers' names deliberately withheld.

[b] Thermal MW.

[c] NR = No response.

[d] NA = Not applicable. Manufacturer does not produce systems in this size range.

TABLE 3-18. MANUFACTURERS WILLING TO CONTRACT FOR OPERATION AND/OR MAINTENANCE OF FABRIC FILTERS AND THE EFFECTS OF CONTRACTS ON GUARANTEES

Company[a]	Effect on guarantees
D	More comprehensive guarantee (considered only in isolated cases)
G	No comment about effect on guarantees
J	Guaranteed availability

[a] Manufacturers' names deliberately withheld.

TABLE 3-19. FABRIC FILTER GUARANTEES

Company[a]	Particulate removal	Predetermined installation cost	Availability	Other
A	Yes--efficienty	Yes	Yes	
B	Yes--guarantee to meet code when operated ISAW instructions	Yes--fixed price plus escalation	No	Yes--1 year merchantability
C	Yes	Yes	Yes--not to exceed 95 percent	Yes--power consumption, bag life
D	Yes--outlet residual or percentage	Yes--escalation considered	No	Yes--pressure drop, opacity
E	Yes--to meet emission code requirements for mass emissions and opacity, if operated per instructions	Yes--fixed price for contracts less than 1 year; escalation clauses for longer contracts	Yes--100 percent, if operated per instructions	Yes--pressure loss; bag life for 1 year, negotiable; operation per instructions
F	Yes	Yes	Yes	Yes--mechanical parts warranty for 1 year from date of shipment
G	Yes--compliance with applicable codes, when operated per instructions	Yes--turnkey price	Yes--service and operational contracts are available	Yes--bag life, when operated per instructions
H	Yes--maximum outlet mass loading	Yes--subject to BLS escalation	Yes--normally continuous operation	Qualifications--bag life, dew point excursions, startup, and maintenance

(continued)

TABLE 3-19. (continued)

Company[a]	Particulate removal	Predetermined installation cost	Availability	Other
I	Yes--if operated and maintained per instructions	No	No	Yes--bag life in excess of 1 year
J	Yes--mass emission and opacity	Yes--price plus escalation	Yes--with maintenance supervision contract	Yes--power consumption, pressure loss, 2-year bag life

[a] Manufacturers' names deliberately withheld.

TABLE 3-20. PRODUCTION CAPABILITY OF FABRIC FILTER MANUFACTURERS[a]

	1981-1985		1986-1990		1991-1995	
	Present staff	Expanded staff	Present staff	Expanded staff	Present staff	Expanded staff
Design capability						
Number	451	915	758	1,345	982	1,892
Capacity, MW equivalent[b]	20,130	42,200	36,140	64,410	47.330	79,870
Installation capability						
Number	275	453	398	708	514	1,068
Capacity, MW equivalent[b]	12,530	21,330	20,010	33,090	26,070	47,880

[a] Represents the responses of 9 manufacturers.

[b] Thermal MW.

TABLE 3-21. TIME FOR DESIGN AND INSTALLATION OF FABRIC FILTERS
(months)

Company[a]	2.9 to 7.3 MW[b]		7.3 to 14.7 MW[b]		14.7 to 29.3 MW[b]		29.3 to 73.3 MW[b]		>73.3 MW[b]	
	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range
A	4	3-5	4	3-5	4	4-6	5	5-7	6	6-8
B	9	7-14	9	7-14	9	7-14	16	10-22	22	16-28
C	10	8-12	12	10-14	14	12-16	16	14-18	20	18-22
D	4.5	4-6	6.5	6-8	9	8-12	NA[c]	NA	NA	NA
E	6	5-8	6	5-8	6	5-9	8	6-11	12	11-16
F	5	4-8	5	4-8	6	5-9	8	5-10	10	8-14
G	1	0.75-1.25	1.5	1-2	2	1.5-2.5	2	1.5-2.5	3	2-4
H	9	8-10	9	8-10	12	10-14	13	11-15	13	11-15
I	3	2-4	3	2-4	4	3-6	4	3-6	6	4-8
J	8	8-12	9	8-12	12	10-14	18	14-20	24	20-26

[a] Manufacturers' names deliberately withheld.

[b] Thermal MW.

[c] NA = Not applicable. Manufacturer does not produce systems in this size range.

TABLE 3-22. TIME FOR STARTUP OF FABRIC FILTERS
(months)

Company[a]	2.9 to 7.3 MW[b]		7.3 to 14.7 MW[b]		14.7 to 29.3 MW[b]		29.3 to 73.3 MW[b]		>73.3 MW[b]	
	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range
A	0.4	0.25-1	0.5	0.25-1	0.5	0.25-1	0.75	0.5-1.25	0.75	0.5-1.25
B	1	1-2	1	1-2	1	1-2	1	1-2	1	1-2
C	0.5	0.25-1	0.5	0.25-1	0.5	0.25-1	0.75	0.5-1	1	0.55-1.5
D	0.75	0.5-1	1	1-1.5	1.25	1-2	NA[c]	NA	NA	NA
E	0.25	0.2-0.5	0.25	0.2-0.5	0.5	0.3-1	1	0.5-2	2	1-3
F	0.5	NR[d]	0.5	NR	1	0.5-2	1	0.5-2	1	0.5-2
G	1	0.75-1.25	1	0.75-1.25	1	0.75-1.25	1	0.75-1.25	1	0.75-1.25
H	<1	NR	<1	NR	1	NR	1	NR	1	NR
I	1	0.5-1.5	1	0.5-1.5	1	0.5-1.5	1	0.5-1.5	1	0.5-1.5
J	0.4	0.3-0.8	0.8	0.7-1.0	0.8	0.7-1.0	0.9	0.7-1.2	1	0.7-1.4

[a] Manufacturers' names deliberately withheld.

[b] Thermal MW.

[c] NA = Not applicable. Manufacturer does not produce systems in this size range.

[d] NR = Not reported. Manufacturer did not supply required information.

TABLE 3-23. LABOR DISTRIBUTION IN THE MANUFACTURE AND CONSTRUCTION OF FABRIC FILTERS[a]
(percentages)

Company[b]	Process design		Detailed design		Equipment fabrication		System installation			
							Supervision		Craft	
	In[c]	Out[d]	In[c]	Out[d]	In[c]	Out[d]	In[c]	Out[d]	In[c]	Out[d]
A	5	5	25	5	65	25	0	10	5	60
B	100	0	100	0	17	83	50	50	0	100
C	35	0	35	0	0	100	15	0	15	0
D	100	0	80	20	20	80	20	80	0	100
E	100	0	100	0	75	25	100	0	0	100
F	100	0	100	0	95	5	60	40	0	100
G	100	0	95	5	0	100	100	0	0	100
H	100	0	100	0	30	70	100	0	0	100
I[e]	100	0	66	33	1	99	83	17	0	100
J	100	0	100	0	60	40	100	0	10	90

[a] Values listed as given by manufacturers; some values may not add up to 100%.

[b] Manufacturers' names deliberately withheld.

[c] Work done in-house.

[d] Work contracted out.

[e] See Section 3.3.4.

TABLE 3-24. INCREASED MANPOWER REQUIRED TO MEET EXPANDED FABRIC FILTER PRODUCTION DURING 1981-1985
(man-years/year)

Company[a]	Design	Engineering	Craft[b]	Administration
A	10	8	100	30
B	4	2	c	1
C	10	10	30	10
D	3	2	0	1
E	6	3	0	1
F	0.266	0.2	1.33	0.2
G	300	120	0	200
H	NR[d]	NR	NR	NR
I	2	5	5	2
J	NR	NR	NR	NR

[a] Manufacturers' names deliberately withheld.

[b] Because craft labor is supplied by external contractors, the total increase in craft labor demand will be far greater than indicated in this table.

[c] Manufacturer indicated a question mark.

[d] NR = No response.

TABLE 3-25. LIMITING ITEM ANALYSIS FOR FABRIC FILTERS

	Leadtime, months		Critical path item, %[a]		Delay frequency, %[a]			Supplier, %[a]		
	Average	Range	Yes	No	High	Average	Low	Internal	External	Both
Process design	1.1	0.25-3	67	11	55	22		67	0	0
Detailed engineering design	2.4	0.75-6	78	11	11	55	11	67	0	0
Equipment fabrication										
Unspecified	5.25	3-6	11	0	0	11	11	0	0	11
Structural	3.33	3-4	11	22	11	22	0	0	22	0
Housing	3.6	1.5-8	44	33	33	44	0	22	33	0
Bags	2.8	1-6	0	33	0	11	22	11	22	0
Fans/motors	3.25	2.5-4	22	0	22	0	0	0	22	0
Electrical/controls	3.3	1.75-8	33	33	11	44	11	11	44	0
Equipment installation	3.8	0.25-12	67	11	22	67	0	22	44	0

[a] Values indicate the percentage of the manufacturers listed in Table 3-14 that responded to each question.

TABLE 3-26. KEY FACTORS DELAYING FABRIC FILTERS AND CORRECTIVE ACTIONS RECOMMENDED BY MANUFACTURERS

Company[a]	Delay cause	Corrective action
A	Design: customer design changes Construction and startup: availability of fabrication space; geographic location and climatic conditions	Define equipment specifications clearly; use standard, not custom-designed units; offer bonus clause for early finish
B	No comment	No comment
C	Owner/A&E delay in "turnaround" of drawings for approval, restrictions to construction site access, delays in general construction, startup of ancillary or concurrently furnished equipment	Purchase "turnkey" systems with maximum scope to single supplier
D	Delays in vendor selection, evaluation of bids, terms and preliminary engineering by purchaser; system engineering and final purchaser approval for fabrication; fabrication and design of custom-made components	Advancement of the "state of the art" and environmental regulations to allow purchaser to develop firm specifications and design requirements at the time a bid is requested; on retrofit projects, obtain the assistance of a qualified impartial engineering concern for preliminary system design, evaluation of bids, and performance of field engineering tasks prior to euqipment purchase
E	Design and fabrication: specification changes after job is started Construction: weather and labor disputes Slow governmental approval	Reduce approval time

(continued)

TABLE 3-26 (continued)

Company[a]	Delay cause	Corrective action
F	Approval delays, errors in design, excessive workload of engineers, equipment changes	NR[b]
G	Delays from external suppliers	External suppliers should increase their manufacturing capacity
H	Intermediaries between supplier and ultimate owner	NR
I	None	None required
J	Engineering change orders, delays by fan suppliers and external vendors	Project management expediting purchase orders

[a] Manufacturers' names deliberately withheld.

[b] NR = No response.

TABLE 3-27. MANUFACTURERS OF MECHANICAL COLLECTORS

Company	Description
American Standard Inc., Industrial Products Division	Cyclone Multibar
Envirotech Corp., Buell Emission Control Division	Cyclones (dry and wet) Multibar
Universal Oil Products, Inc., Air Correction Division	Cyclone

TABLE 3-28. MECHANICAL COLLECTOR GUARANTEES

Company[a]	Particulate removal	Predetermined installation cost	Availability	Other
A	Yes--conditions of applicable performance curve must be met; limited liability	No	No	Yes--delivery and pressure drop, limited liability for both
B	Yes--as measured by ASME field testing and qualified by particulate sizing and system conditions	No	No	None
C	Yes--based on fractional efficiency curve and inlet gas conditions	No	No	Yes--fractional efficiency, pressure drop

[a] Manufacturers' names deliberately withheld.

TABLE 3-29. PRODUCTION CAPABILITY OF MECHANICAL COLLECTOR MANUFACTURERS

	1981-1985		1986-1990		1991-1995	
	Present staff	Expanded staff	Present staff	Expanded staff	Present staff	Expanded staff
Design capability[a]						
Number	50	70	60	80	70	90
Capacity, MW equivalent[b]	1000	1400	1400	1600	1400	1800
Installation capability[c]						
Number	0	0	0	0	0	0
Capacity, MW equivalent[b]	0	0	0	0	0	0

[a] Represents the responses of one manufacturer only.

[b] Thermal MW.

[c] Products are furnished on a flange-to-flange basis only. Neither manufacturer installs systems. Supervision of installation may be offered.

TABLE 3-30. LABOR DISTRUBUTION IN THE MANUFACTURE
AND CONSTRUCTION OF MECHANICAL COLLECTORS
(percentages)

Company[a]	Process design		Detailed design		Equipment fabrication		System installation			
							Supervision		Craft	
	In[b]	Out[c]	In[b]	Out[c]	In[b]	Out[c]	In[b]	Out[c]	In[b]	Out[c]
A	None	None	50	50	0	100	None	None	None	None
B	100	0	100	0	100	0	100	0	0	100
C	100	0	100	0	0	90	0	100	0	100

[a] Manufacturers' names deliberately withheld.

[b] Work done in-house.

[c] Work contracted out.

TABLE 3-31. INCREASED MANPOWER REQUIRED TO MEET EXPANDED MECHANICAL COLLECTOR PRODUCTION
(man-years/year)

Company[a]	Design	Engineering	Craft	Administration
A	NR[b]	NR	NR	NR
B	5	3	20	2
C	NR	NR	NR	NR

[a] Company names deliberately withheld.

[b] NR = No response.

TABLE 3-32. KEY FACTORS DELAYING MECHANICAL COLLECTORS AND CORRECTIVE ACTIONS RECOMMENDED BY MANUFACTURERS

Company[a]	Delay cause	Corrective action
A	Subcontractor delays	Not applicable[b]
B	Understaffed engineering group, delays in drawing approval, lack of availability of materials of construction, poor plant operational procedures	Not applicable[b]
C	Usually none	Not applicable

[a] Manufacturers' names deliberately withheld.

[b] Data reported as given by manufacturer.

TABLE 3-33. MAN-HOURS PER YEAR REQUIRED FOR OPERATION, MAINTENANCE, AND SUPERVISION OF A WET SCRUBBER

Company[a]	2.9 to 7.3 MW[b]	7.3 to 14.7 MW[b]	14.7 to 29.3 MW[b]	29.3 to 73.3 MW[b]	>73.3 MW[b]
Operation					
A[c]	3500	3500	3500	3500	7000
B	d	d	d	d	d
Maintenance					
A	1750	1750	1750	1750	3500
B	d	d	d	d	d
Supervision					
A	1750	1750	1750	1750	3500
B	d	d	d	d	d

[a] Manufacturers' names deliberately withheld.

[b] Thermal MW.

[c] This manufacturer's responses were based on an operating factor of 7000 hours per year.

[d] Combined requirements for operation, maintenance, and supervision are 2,200 man-hours per year.

TABLE 3-34. MANUFACTURERS WILLING TO CONTRACT FOR OPERATION AND/OR MAINTENANCE OF WET SCRUBBERS AND EFFECTS OF CONTRACTS ON GUARANTEES

Company[a]	Effect on guarantees
A	More stringent guarantees
B	Generally improved guarantees concerning utility consumption and availability

[a] Manufacturers' names deliberately withheld.

TABLE 3-35. WET SCRUBBER GUARANTEES

Company[a]	Particulate removal	Predetermined installation cost	Availability	Other
A	Yes	Yes	Yes	NR[b]
B	Yes--unlimited liability	Yes--lump sum plus escalation; cost plus fixed fee	Yes	Yes--utilities, pressure drop, liquidated damages basis

[a] Manufacturers' names deliberately withheld.

[b] NR = No response.

TABLE 3-36. PRODUCTION CAPABILITY OF WET SCRUBBER MANUFACTURERS

	1981-1985		1986-1990		1991-1995	
	Present staff	Expanded staff	Present staff	Expanded staff	Present staff	Expanded staff
Design capability						
Number	55	110	60	140	65	175
Capacity, MW equivalent[a]	1350	2700	1450	3425	1550	4250
Installation capability						
Number	28	57	32	70	35	90
Capacity, MW equivalent[a]	685	1390	765	1700	825	1175

[a] Thermal MW.

TABLE 3-37. TIME REQUIRED FOR DESIGN, INSTALLATION, AND STARTUP OF WET SCRUBBERS[a]
(months)

Size, MW	Design and installation		Startup	
	Average	Range	Average	Range
2.9 to 7.3	10	8-12	1	0.5-3
7.3 to 14.7	10	8-12	1	0.5-3
14.7 to 29.3	14	12-16	1	0.5-3
29.3 to 73.3	14	12-16	1	0.5-3
>73.3	24	18-30	1	0.5-3

[a] Represents the responses of only one manufacturer whose name is deliberately withheld.

TABLE 3-38. LABOR DISTRIBUTION IN THE MANUFACTURE AND CONSTRUCTION OF WET SCRUBBERS (percentages)

							System installation			
	Process design		Detailed design		Equipment fabrication		Supervision		Craft	
Company[a]	In[b]	Out[c]	In[b]	Out[c]	In[b]	Out[c]	In[b]	Out[c]	In[b]	Out[c]
A	100	0	100	0	0	100	25	75	0	100
B	100	0	100	0	0	100	10	90	0	100

[a] Manufacturers' names deliberately withheld.

[b] Work done in-house.

[c] Work contracted out.

TABLE 3-39. INCREASED MANPOWER REQUIRED TO MEET EXPANDED WET SCRUBBER PRODUCTION
(man-years/year)

Company[a]	Design	Engineering	Craft[b]	Administration
A	96	36	0	18
B	2	2	0.5	0.5

[a] Manufacturers' names deliberately withheld.

[b] Because most craft labor is supplied by external contractors, the total increase in craft labor demand will be greater than indicated in this table.

TABLE 3-40. KEY FACTORS DELAYING WET SCRUBBERS AND CORRECTIVE ACTIONS RECOMMENDED BY MANUFACTURERS

Company[a]	Delay action	Corrective action
A	Client approval of P&ID and general arrangement drawings, late delivery of equipment	Follow critical path schedule
B	Design changes, lack of communication, and decision making	Eliminate factors listed as much as possible

[a] Manufacturers' names deliberately withheld.

SECTION 4

TREATMENT OF NO_x IN FLUE GAS

4.1 INTRODUCTION

Treatment of NO_x in flue gas is the least developed of the control technologies discussed in this report. Flue gas treatment (FGT) systems have been used commercially at several plants in Japan and at one plant in the United States.[4] As expected, lack of demand and of manufacturing and installation experience severely limit the information available for this survey.

After a wide-ranging telephone survey of potential manufacturers of flue gas treatment systems, survey forms were sent to eight companies and five responded. Envirotech/Chemico Air Pollution Control completed the survey form, Exxon refused to participate due to work pressure, and Research Cottrell refused to participate due to a confidentiality agreement with the licenser (Exxon). Two other companies did respond, but could not complete the survey form because they did not produce flue gas treatment systems to control NO_x emissions from industrial boilers.

Because of the limited response, restricted data are presented to maintain the manufacturer's confidentiality. Where appropriate, data from the literature are used to supplement data from the survey.

4.2 MANUFACTURERS' PRODUCTS

4.2.1 System Description

Table 4-1 lists the companies involved in flue gas treatment for NO_x control.

Envirotech/Chemico Air Pollution Control produces a catalytic reduction system under license from Hitachi Zosen of Tokyo, Japan. The process operates at a ratio of about 1 mole of ammonia (NH_3) to 1 mole of nitrogen oxide (NO) and a temperature from 350° to 400°C (662° to 752°F). The NO_x removal efficiency ranges up to 95 percent.[5]

Exxon is the licenser of a thermal denitrification process. Generally, this type of process involves the injection of ammonia into flue gases at roughly 1000°C. Rapid mixing of the gases is achieved by a refractory structure.[6] Exxon has found that addition of hydrogen with the ammonia can reduce the reaction temperature to 730°C.[7] Laboratory tests have achieved 80 percent reduction in NO_x at carefully controlled conditions. In a large scale operation, approximately 50 percent NO_x removal is expected at an NH_3/NO mole ratio of 1.5 to 2.0.[6] Research Cottrell markets the Exxon process under license.

Both processes produce nitrogen and water as byproducts.

4.2.2 Limiting Item Analysis

None of the manufacturers listed in Table 4-1 supplied information for a limiting item analysis. The Tennessee Valley Authority, however, through an interagency agreement with the U.S. Environmental Protection Agency (EPA), has performed a study on the impact of ammonia utilization in FGT technologies. If FGT were only required on new industrial boilers with heat inputs greater than 73.3 MW thermal, the ammonia generating industry could readily adapt to the development of the FGT industry, and ammonia supply would be no problem. Requiring FGT on all existing large boilers would significantly distort the NH_3 market and adversely affect the fertilizer industry.[8]

4.3 OTHER SYSTEMS

Apart from the two systems listed in Table 4.1, many other systems are used in foreign countries or are still being developed. These processes have been reviewed in the literature.[4,9,10,11,12]

4.4 SIMULTANEOUS REMOVAL OF SO_2 AND NO_x

The initial telephone survey indicated that no companies were willing to provide data about systems to remove SO_2 and NO_x simultaneously. The literature, however, reports that Universal Oil Products has carried out a pilot-scale investigation of a catalytic process developed by Shell. The test unit was connected to coal-fired boilers at Tampa Electric Company's Big Bend Station in Florida. The Shell process was expected to remove 90 percent of both SO_2 and NO_x. This level was achieved for SO_2, but not for NO_x from the coal-derived flue gas.[5]

Chiyoda has made a simple modification to the Thoroughbred 101 FGD process to remove NO_x. The modified system can remove 60 percent of NO_x and 90 percent of SO_2.[13]

Other processes have been developed by Japanese manufacturers.[4]

TABLE 4-1. MANUFACTURERS OF SYSTEMS FOR THE TREATMENT OF NO_x IN FLUE GAS

Company	System
Envirotech/Chemico Air Pollution Control	Catalytic reduction with ammonia
Exxon	Thermal reduction with ammonia
Research Cottrell	Thermal reduction with ammonia[a]

[a] Exxon licensee.

SECTION 5

COMBUSTION MODIFICATIONS FOR NO_x CONTROL

5.1 INTRODUCTION

Some techniques of combustion modification for NO_x control are well established, but others are still in early development. The present and proposed utility boiler NSPS allow combustion modifications to meet the regulations. If more stringent limits are established for NO_x emissions from industrial boilers, the boiler industry may have to use flue gas treatment in addition to, or in place of, combustion modifications.

A telephone survey was made of 15 companies with a potential interest in combustion modification, some of which are listed in the literature as using or developing combustion modifications.[14] A poor response was obtained, and some companies denied any involvement in the field. Ten survey forms were issued to manufacturers. Two completed the form, and a third supplied some data by letter. These responses are summarized below.

5.2 MANUFACTURERS' PRODUCTS

5.2.1 System Descriptions

Table 5-1 lists the systems supplied by the manufacturers that responded to the survey. The following information was provided by the manufacturers:

- All systems are available for new and retrofit applications, but the latter can be limited by boiler configuration.
- One manufacturer's system was only suitable for oil- and gas-fired boilers.

- Most systems are custom-designed, but some off-the-shelf systems are available for small package boilers.
- Half of the equipment is manufactured under license.
- Combustion modifications are available for boilers with heat inputs from 1 to 73.3 MW thermal. Financial, not technical, considerations limit the range.

5.2.2 Manpower Requirements

Manufacturers reported that no additional manpower would be required for operation, maintenance, and supervision of combustion modification systems. All these functions could be carried out by existing personnel. No manufacturer is willing to provide maintenance services, but one might do so if production increased enough.

5.3 MANUFACTURERS' GUARANTEES

Table 5-2 presents the guarantee data reported by the manufacturers. Both manufacturers that responded are willing to guarantee a reduction in NO_x levels.

5.4 CAPABILITIES OF MANUFACTURERS

The reported manufacturing capabilities are presented in Table 5-3. The survey form stated: "Indicate the number and total equivalent MW of new systems, operating at the maximum efficiency previously stated, that you can design and install in the periods indicated with current and planned staff additions. Also indicate your capacity using an expanded staff or more extensive use of subcontractors. Design or installation work that has already been started is excluded from these figures." The one manufacturer that supplied data in response to this question reported that production was independent of emission control efficiency. One manufacturer did not respond, and the third stated only that the maximum annual increase in staff would be no more than 10 percent, because of the company objective of controlled growth.

Table 5-4 presents data about the increased manpower required to meet the expanded production shown in Table 5-3.

Table 5-5 presents data supplied about the time required for design and installation of various combustion modifications. One manufacturer's leadtime is twice that of the other. Table 5-6 presents the data supplied about the time required for startup of combustion modification systems. Most startups are less than 3 months, and the startups of smaller units are faster than those of larger units.

Table 5-7 presents data on the distribution of personnel in the manufacture and construction of combustion modification systems. All process design is done internally; one manufacturer contracts much of the fabrication. Installation is always supervised by company personnel; the construction labor is contracted.

5.5 LIMITING ITEM ANALYSIS

Table 5-8 is a limiting item analysis of the basic elements associated with the development and construction of a combustion modification system. The data are very limited, and conclusions drawn from them may be misleading. Long leadtimes and delays do not appear to be problems. Variations between the two manufacturers appear to be small.

Table 5-9 presents key factors listed by the manufacturers as delaying in the design, construction, and startup of combustion modification systems for NO_x control. This table also lists one suggested corrective action.

TABLE 5-1. MANUFACTURERS OF COMBUSTION MODIFICATION SYSTEMS FOR NO_x CONTROL

Company	System description
CEA Combustion, Inc.	Combustion modifications consisting of one or more of the following: 1. Off-stoichiometric (O/S) combustion 2. Two-stage combustion 3. Leaving burners out of service 4. Biased firing 5. Low excess air 6. Flame temperature reduction 7. Flue gas recirculation 8. Air preheat reduction
Coen Company	Combustion modifications consisting of one or more of the following: 1. NO_x ports 2. Off-ratio firing 3. Biased firing 4. Flue gas recirculation 5. Low excess air
TRW Energy Systems Group	Low NO_x emissions burner that fires conventionally over load range

TABLE 5-2. GUARANTEES FOR COMBUSTION MODIFICATION SYSTEMS FOR NO_x CONTROL

Company	NO_x reduction efficiency	Predetermined installation cost	Availability	Other
A	Yes--percent reduction or absolute minimum value, whichever is less stringent, subject to installation and operation in accordance with design specifications	Yes--fixed price with escalation clause, subject to installation and operation in accordance with design specifications	Yes--to meet design rating of fixed equipment, subject to installation and operation in accordance with design specifications	Standard warranty for defects and workmanship for 1 year from date of shipment, subject to installation and operation in accordance with design specifications
B	Yes--qualified by fuel characteristics, manual operation at full load only; negotiated maximum liability	No	No	No
C	NR[b]	NR[b]	NR[b]	NR[b]

[a] Manufacturers' names deliberately withheld.

[b] NR = No response.

TABLE 5-3. PRODUCTION CAPABILITY OF MANUFACTURERS OF MODIFICATION SYSTEMS FOR NO_x CONTROL[a]

	1981-1985		1986-1990		1991-1995	
	Present staff	Expanded staff	Present staff	Expanded staff	Present staff	Expanded staff
Design capability						
Number	30	300	40	550	45	700
Capacity, MW equivalent[b]	330	3,300	880	12,100	990	15,400
Installation capability						
Number	25	250	35	450	40	600
Capacity, MW equivalent[b]	280	2,750	770	9,900	880	13,200

[a] This table represents the response of one manufacturer whose name is deliberately withheld.

[b] Thermal MW.

TABLE 5-4. ADDITIONAL STAFF REQUIRED TO ACHIEVE EXPANDED PRODUCTION[a]
(man-years/year)

	1981-1985	1986-1990	1991-1994
Design	12	19	24
Engineering	28	45	56
Craft	b	b	b
Administration	9	25	18

[a] Manufacturers' name deliberately withheld.

[b] Subcontracted.

TABLE 5-5. TIME FOR DESIGN AND INSTALLATION OF COMBUSTION MODIFICATION SYSTEMS FOR NO_x CONTROL (months)

Company[a]	2.9 to 7.3 MW[b]		7.3 to 14.7 MW[b]		14.7 to 29.3 MW[b]		29.3 to 73.3 MW[b]		>73.3 MW[b]	
	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range
A	4	3-5	4	3-5	4	3-6	6	4-7	7	5-8
B	8	4-9	8	4-9	8	6-9	12	9-16	12	9-16
C	NR[c]	NR	NR	NR	NR	NR	NR	NR	NR	NR

[a] Manufacturers' names deliberately withheld.

[b] Thermal MW.

[c] NR = No response.

TABLE 5-6. TIME FOR STARTUP OF COMBUSTION MODIFICATION SYSTEMS FOR NO_x CONTROL (months)

Company[a]	2.9 to 7.3 MW[b]		7.3 to 14.7 MW[b]		14.7 to 29.3 MW[b]		29.3 to 73.3 MW[b]		>73.3 MW[b]	
	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range
A	0.5	0.5-1	0.4	0.5-1	0.5	0.5-1	0.5	0.5-1	1	0.5-2
B	2	1-3	2	1-3	3	2-5	3	2-5	3	2-5
C	NR[c]	NR	NR	NR	NR	NR	NR	NR	NR	NR

[a] Manufacturers' names deliberately withheld.

[b] Thermal MW.

[c] NR = No response.

TABLE 5-7. LABOR DISTRIBUTION IN THE MANUFACTURE AND CONSTRUCTION OF COMBUSTION MODIFICATION SYSTEMS FOR NO_x CONTROL (percentages)

							System installation			
	Process design		Detailed design		Equipment fabrication		Supervision		Craft	
Company[a]	In[b]	Out[c]	In[b]	Out[c]	In[b]	Out[c]	In[b]	Out[c]	In[b]	Out[c]
A	100	0	100	0	20	80	100	0	0	100
B	NR[d]	NR	NR	NR	NR	NR	NR	NR	NR	NR
C	100	0	100	0	100	0	100	0	0	100

[a] Manufacturers' names deliberately withheld.

[b] Work done in-house.

[c] Work contracted out.

[d] NR = No response.

TABLE 5-8. LIMITING ITEM ANALYSIS FOR COMBUSTION MODIFICATION SYSTEMS FOR NO_x CONTROL[a]

	Leadtime, months		Critical path item, %[a]		Delay frequency, %[a]		
	Range	Mean	Yes	No	High	Average	Low
Process design	0.5-1	0.75	33	0	33	0	0
Detailed engineering design	1-2	1.5	33	0	33	0	0
Equipment fabrication							
Unspecified	3	3	33	0	33	0	0
Registers	3	3	0	0	0	0	0
Burners	3	3	0	0	0	0	0
Control system	4	4	0	0	0	0	0
Equipment installation	0.5-2	1.25	33	0	0	33	0

[a] Values indicate the percentage of the manufacturers listed in Table 5-1 that responded to each question.

TABLE 5-9. KEY FACTORS DELAYING COMBUSTION MODIFICATIONS SYSTEMS FOR NO_x CONTROL AND CORRECTIVE ACTIONS RECOMMENDED BY MANUFACTURERS

Company[a]	Delay cause	Corrective action
A	Installation dependent on subcontractor with insufficient manpower	Develop in-house construction capability
B	NR[b]	NR
C	Lack of clear understanding by Government agencies of what is required to satisfy requirements; lack of adequate manpower to custom-design each unit	NR

[a] Manufacturers' names deliberately withheld.

[b] NR = No response.

SECTION 6
CONCLUSIONS

6.1 FLUE GAS DESULFURIZATION SYSTEMS

Figure 6-1 summarizes the data reported about FGD systems. This figure indicates the number of systems that manufacturers stated they could design and install in each 5-year period from 1981 through 1995 with the present and expanded production capabilities discussed in Section 2.4. The number of new coal-fired boilers that will be installed during each period is also shown; units with heat inputs from 2.9 to 7.3 MW thermal and from 7.3 to 14.7 MW thermal are differentiated from larger boilers.

Only 75 percent of the manufacturers surveyed about FGD systems responded. Figure 6-2 estimates the total production capability of FGD system manufacturers on the assumption that the nonresponding manufacturers can produce proportionately as many systems as the responding ones. This figure suggests that even with expanded staffs, the manufacturers could design FGD systems for only about 50 percent of the new coal-fired boilers from 1980 to 1985 and can install even less. In subsequent periods, the situation would be worse. The overall position would drastically improve if FGD systems were not required for smaller boilers.

The production capabilities in Figures 6-1 and 6-2 are based on an 85 percent SO_2 removal efficiency. The data for a 90 percent SO_2 removal efficiency differ only marginally from these capabilities. If an efficiency of at least 95 percent were required, however, the capability of manufacturers would decline by about 50 percent in each 5-year period from the capability shown in the figures.

6.2 PARTICULATE CONTROL SYSTEMS

Figure 6-3 summarizes the data reported about ESP's and fabric filters. The results are presented in the format used in Figure 6-1. The data represent the responses of 44 percent of the ESP manufacturers that were sent survey forms and 50 percent of the fabric filter manufacturers that were sent survey forms. The number of systems that the manufacturers can design is of greater significance than the number of systems they can install because manufacturers usually do not install particulate control systems, especially on small industrial boilers.

Figure 6-4 suggests that if allowance is made for the nonresponding companies, which included a few major manufacturers, and assuming sufficient installation contractors, enough particulate control systems will be available for new coal-fired boilers. Several manufacturers stated that production capability would be sufficient, and one manufacturer predicted that production would fall from 1991 to 1995 because of market saturation.

6.3 NO_x EMISSION CONTROL SYSTEMS

The two methods of NO_x emission control reviewed in this survey are FGT and combustion modification. An FGT system can reduce NO_x emissions by up to 95 percent. A combustion modification system can reduce NO_x emissions by up to 85 percent, 15 although the common removal efficiency is about 50 percent.

The technology of FGT is slowly developing, and a few manufacturers are entering the field. Insufficient data were obtained concerning the future production capability of FGT system manufacturers. Because these manufacturers also make FGD systems, a rapid expansion in FGT system production could detrimentally affect the production of FGD units. In addition, a rapid expansion in FGT system production would significantly affect the ammonia market and consequently the fertilizer and food industries.

Combustion modification technology is more firmly established than FGT technology, although only limited data concerning production capabilities could be obtained. The data suggest an extreme shortage of combustion modification systems, especially if controls were required on oil- and gas-fired boilers in addition to coal-fired boilers. If low-NO_x burners were required, many burner manufacturers might produce them, possibly under special license because the standard burners would become obsolete.

One manufacturer commented that unnecessarily strict NO_x emission limits would jeopardize the existence of independent burner companies. The comment was:

> "If the new EPA NO_x limits are set unnecessarily low, such that there is a small margin between the limit and that what can be obtained with the best burner technology, there will be a real possibility that the limit will not always be achieved. Not achieving a limit could result in forced boiler shutdown, loss of production, expensive boiler modifications and resulting lawsuits. When independent burner manufacturers sell their burners to the boiler companies, it is industry practice for the burner company to limit their liability to the price of the burner order or to some negotiated higher amount. It is very possible that a 30,000 dollar burner order could result in hundreds of thousands of dollars in damages, if an emission limit were not met. Because of this potential risk, there will be resistance by the boiler manufacturer to carry an independent burner manufacturer, even if specified by the ultimate customer. The point I am making is that unnecessarily or unrealistically strict emission limits may force the boiler companies to try to 'control' their risks by using their own burners and not those of independent burner manufacturers. This would significantly change the market place as it exists today."

If strict NO_x emission limits were set, a combined FGT and combustion modification system could be used. Such a system could achieve the same emission reduction with lower operating costs than an FGT system alone and would affect the ammonia market less. A combined system, however, would still depend on the very limited production capability of FGT system manufacturers.

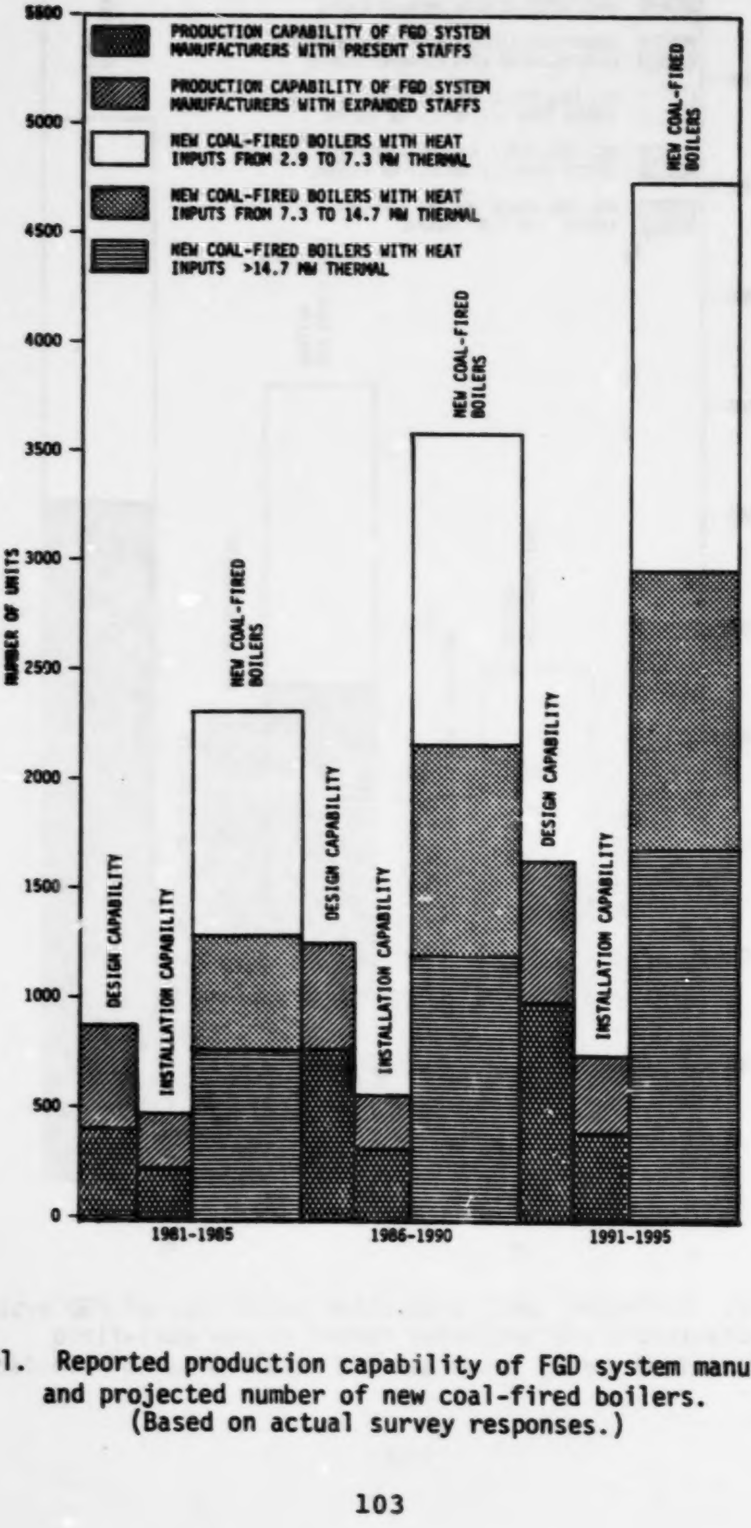

Figure 6-1. Reported production capability of FGD system manufacturers and projected number of new coal-fired boilers. (Based on actual survey responses.)

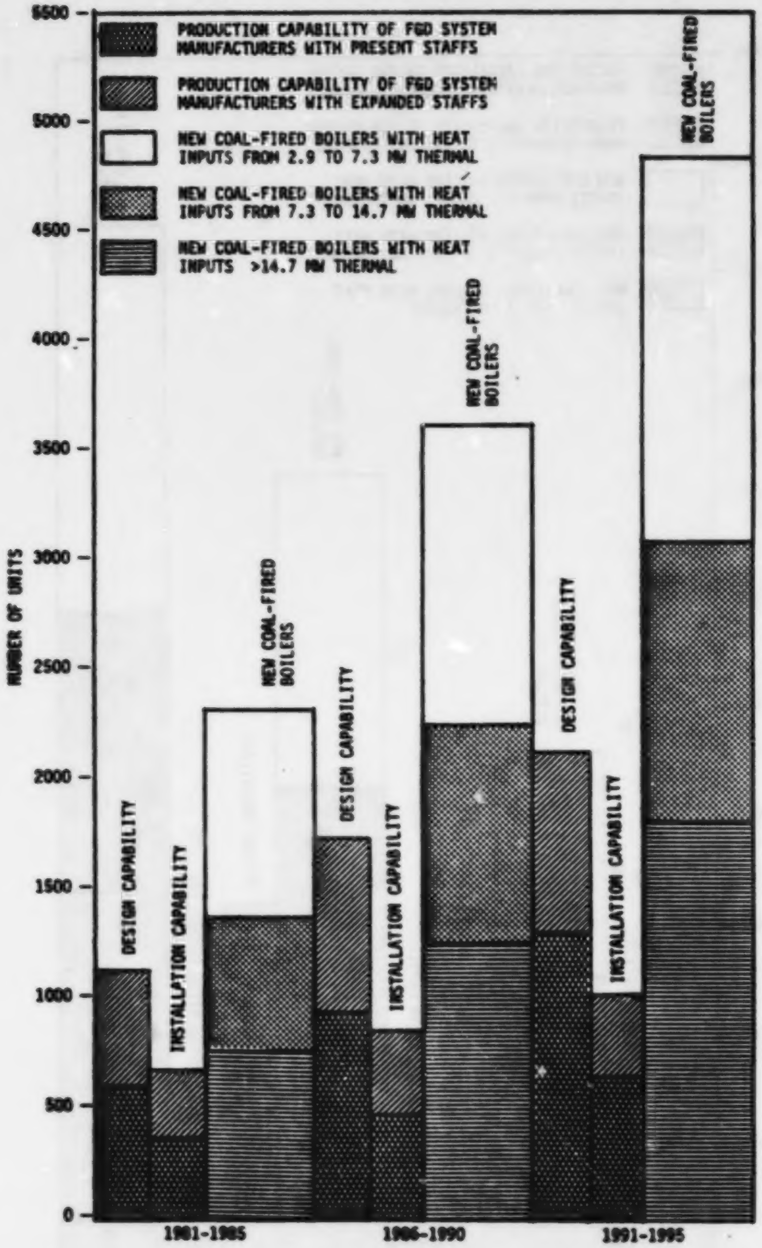

Figure 6-2. Estimated total production capability of FGD system manufacturers and projected number of new coal-fired boilers projected from survey responses and total number of manufacturers.

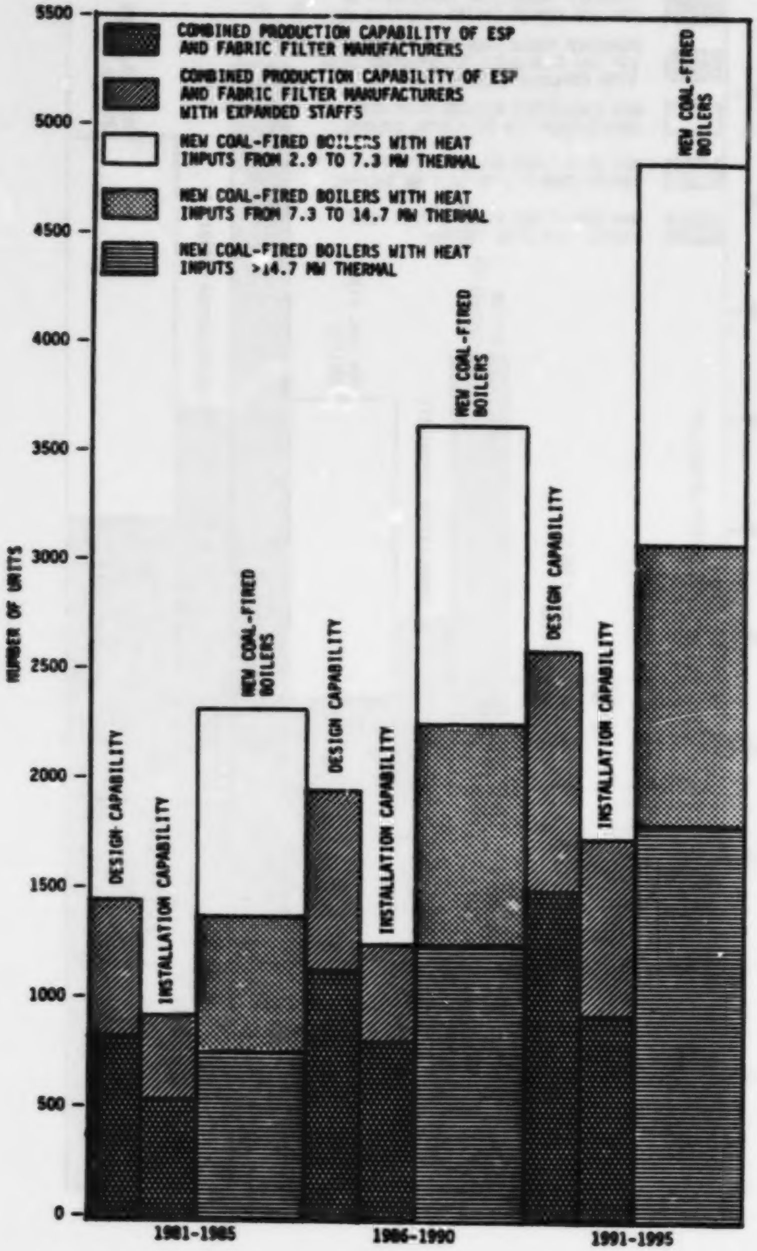

Figure 6-3. Reported production capability of fabric filter and ESP manufacturers and projected number of new coal-fired boilers. (Based on actual survey responses.)

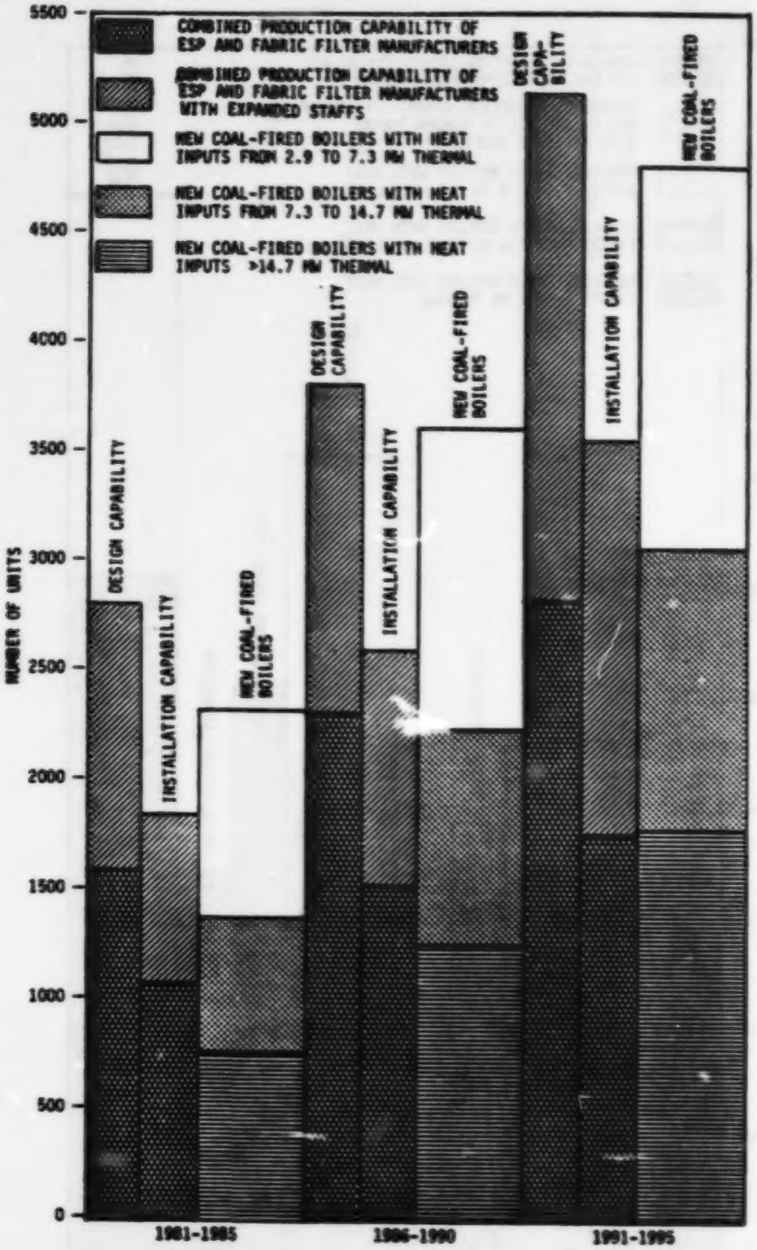

Figure 6-4. Estimated total production capability of fabric filter and ESP manufacturers and projected number of new coal-fired boilers projected from survey responses and total number of manufacturers.

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12. Acurex Corporation. NO_x Control Review, 4(1):7-8, EPA-68-02-2160, 1979.

13. Op. cit. No. 4, pp. 129-130.

14. Op. cit. No. 10, pp. 3-4.

15. Op. cit. No. 9, p. 2.

APPENDIX A

SURVEY FORM SENT TO MANUFACTURERS OF FLUE GAS DESULFURIZATION SYSTEMS

Flue Gas Desulfurization

Manufacturer's name:

Address:

Name(s) of person(s) completing survey:

Telephone number(s) of above person(s):

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SYSTEM DESCRIPTION

(1) Type of system (attach additional sheets of description, if necessary):

(2) Wet or dry process:

(3) Applicability of system (delete as applicable):

New units: yes/no
Existing units: yes/no
Coal fired: yes/no
Oil: yes/no
Gas: yes/no

(4) Size range: from _____ MW to _____ MW

(5) Maximum SO_2 removal efficiency:

(6) Will the system remove particulates: yes/no
maximum efficiency:

(7) Custom-designed systems or off-the-shelf:

(8) Own process or licensed:

(9) Regenerative or nonregenerative:

(10) FGD raw material considerations:

Raw materials	Manufacturer	Specifications	Availability

(11) FGD system byproducts
Complete either 11a or 11b.

11a - Regenerable systems

(i) What products can be produced (S, H_2SO_4, etc.):

(ii) Is the regeneration facility supplied as part of the process or must the company make separate arrangements:

(iii) What is the demand for the recovered byproduct:

(iv) Will you market the recovered sulfur products for company clients:

11b - Nonregenerable Systems

(i) Amount of sludge produced per lb of SO_2 removed from the flue gas:

(ii) What methods do you offer for sludge treatment:

(iii) Is the sludge potentially toxic or inert:

(iv) Is the final sludge product dry or thixotropic:

(v) Can the sludge be recovered as a by-product:

(vi) Can the system operate on a totally closed loop mode:

* * *

VENDOR GUARANTEES

(12) Indicate the type of guarantees you will provide and briefly describe their conditions and qualifications:

SO_2 removal efficiency: yes/no. Terms:

Particulate removal efficiency: yes/no. Terms:

Predetermined installation cost: yes/no. Terms:

Performance (availability) guarantee: yes/no. Terms:

Other (describe): yes/no. Terms:

Comments (example of qualifications to guarantees):

* * *

FGD OPERATING PERSONNEL REQUIREMENTS

(13) Identify the manpower required for effective operation of the following size FGD systems. Actual numbers will depend on specific company's operating practice:

	Men/shift					Total man-hours/year				
Position	2.9-7.3 MW	7.3-14.7 MW	14.7-29.3 MW	29.3-73.3 MW	>73.3 MW	2.9-7.3 MW	7.3-14.7 MW	14.7-29.3 MW	29.3-73.3 MW	>73.3 MW
Operators										
Maintenance										
Supervisor										

(14) Are you willing to contract for operation and maintenance of the FGD system after installation: yes/no
If yes, comment on effects this will have on system guarantees:

* * *

VENDOR CAPABILITIES

(15) Indicate the number and total equivalent MW of new systems, operating at the maximum efficiency stated in question 5, you can design and install in the periods indicated with current or planned staff additions (do no include any systems that you are currently designing or installing - See question 18). Also indicate your capability with expanded staff or by more extensive use of subcontractors:

	1981-1985		1986-1990		1991-1995	
	Present Staff	Expanded Staff	Present Staff	Expanded Staff	Present Staff	Expanded Staff
Systems Designed						
Number						
MW (Equivalent)						
Systems Installed						
Number						
MW (Equivalent)						

(16) Estimate the manpower increase required to meet the expanded staff capability information provided in (15) above:

Category	Man-years
Designers	________
Engineers	________
Crafts	________
Administrative	________

Do you anticipate any problems in meeting such an expanded staff requirement. If so, how would this modify the above "expanded staff" capability figures:

(17) Indicate the number and total equivalent MW of new systems you can install in the following periods with both current staff and the expanded staff indicated in question 16 if the control efficiency stated in question 5 was reduced by 5 percent and by 10 percent

Five percent reduction

	1981-1985		1986-1990		1991-1995	
	Present Staff	Expanded Staff	Present Staff	Expanded Staff	Present Staff	Expanded Staff
Systems Designed						
Number						
MW (Equivalent)						
Systems Installed						
Number						
MW (Equivalent)						

Ten percent reduction

	1981-1985		1986-1990		1991-1995	
	Present Staff	Expanded Staff	Present Staff	Expanded Staff	Present Staff	Expanded Staff
Systems Designed						
Number						
MW (Equivalent)						
Systems Installed						
Number						
MW (Equivalent)						

(18) Identify your present manpower distribution practices for the following phases of FGD system design, fabrication and installation:

Item	Percent In-House Personnel	Percent Outside Labor[a]
Process Design		
Detailed Engineering Design		
Equipment Fabrication		
Scrubber Vessels/Tanks		
Fan/Pumps		
Sludge Disposal		
System Installation		
Supervision		
Crafts		

[a] For example, subcontractors, job shops, licensee, etc.

* * *

FINANCIAL CONSIDERATIONS

(19) Estimate the costs of the following size FGD systems, operating at the efficiency stated in question 5 on both high sulfur (4.0%) and low sulfur (0.8%) applications:

Size (MW thermal)	Total Installed Costs ($/kW electrical)	Operating/Maintenance costs (Excludes Capital Charges) (mills/kWh).
2.9-7.3		
7.3-14.7		
14.7-29.3		
29.3-73.3		
>73.3		

(20) Describe the extent to which payment method(s) limit the number of FGD system design/installation jobs your firm is willing to undertake (e.g., payment by company, only upon completion of specified project phases may limit

the number of systems undertaken because of cash flow considerations). Also describe the impact the various payment methods have on the time required to design and install FGD systems:

(21) To what extent do available capital resources of the FGD control system manufacturers restrict the number of systems these suppliers are willing to design and the time required to install these systems:

(22) What corrective measures by government and industry do you think are necessary to alleviate financing related problems:

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LIMITING ITEM ANALYSIS

(23) Identify the time required to design, install and start-up various size FGD systems:

Size MW (thermal)	Time Required for Design and Installation		Time Required for Start-up	
	Average	Range	Average	Range
2.9-7.3	_____ months	_____ months to _____ months	_____ months	_____ months to _____ months
7.3-14.7	_____ months	_____ months to _____ months	_____ months	_____ months to _____ months
14.7-29.3	_____ months	_____ months to _____ months	_____ months	_____ months to _____ months
29.3-73.3	_____ months	_____ months to _____ months	_____ months	_____ months to _____ months
>73.3	_____ months	_____ months to _____ months	_____ months	_____ months to _____ months

(24) Estimate the time required to perform the various phases of FGD system design and installation by phase. Also indicate whether the item listed is usually on the critical path and categorize the frequency with which each item leads to overall schedule delays:

	Lead Time (months)	Critical Path Item		Delay Frequency			External Supplier		
		yes	no	High	Average	Low	yes	no	name
Process Design									
Detailed Engineering Design									
Equipment Fabrication									
• Structural Steel									
• Scrubber Vessel/Tanks									
• Fans									
• Pumps									
• Instrumentation									
• Motors									
• Piping									
Equipment Installation									
Reactant Procurement (e.g., limestone)									

(25) Identify the key items or factors leading to delay in the design, construction or start-up of FGD systems:

(26) Identify corrective actions that can be taken by industry, the government and others to overcome delay related problems:

……

APPENDIX B
SURVEY FORM SENT TO MANUFACTURERS OF PARTICULATE CONTROL SYSTEMS

Particulate Control Systems

Manufacturer's name:

Address:

Name(s) of person(s) completing survey:

Telephone number(s) of above person(s):

oooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooo

SYSTEM DESCRIPTION

(1) Type of system (attach additional sheets of description, if necessary):

(2) Wet or dry process:

(3) Applicability of system (delete as applicable):

New units: yes/no
Existing units: yes/no
Coal fired: yes/no
Oil: yes/no
Gas: yes/no

(4) Size range: from _____ MW to _____ MW

(5) Maximum particulate removal efficiency:

(6) Custom-designed systems or off-the-shelf:

(7) Own process or licensed:

(8) Particulate control system raw material considerations:

Raw materials	Manufacturer	Specifications	Availability

(9) Particulate control system byproducts: indicate method of disposal:

……

VENDOR GUARANTEES

(10) Indicate the type of guarantees you will provide and briefly describe their conditions and qualifications:

Particulate removal efficiency: yes/no. Terms:

Predetermined installation cost: yes/no. Terms:

Performance (availability) guarantee: yes/no. Terms:

Other (describe): yes/no. Terms:

Comments (example of qualifications to guarantees).

……

PARTICULATE CONTROL SYSTEM OPERATING PERSONEL REQUIREMENTS

(11) Identify the manpower required for effective operation of the following size systems. Actual numbers will depend on specific company's operating practice.

	Men/shift					Total man-hours/year				
Position	2.9-7.3 MW	7.3-14.7 MW	14.7-29.3 MW	29.3-73.3 MW	>73.3 MW	2.9-7.3 MW	7.3-14.7 MW	14.7-29.3 MW	29.3-73.3 MW	>73.3 MW
Operators										
Maintenance										
Supervisor										

(12) Are you willing to contract for operation and maintenance of the particulate control system after installation: yes/no.

If yes, comment of effects this will have on system guarantees:

……

VENDOR CAPABILITIES

(13) Indicate the number and total equivalent MW of new systems, operating at the maximum efficiency stated in question 5, the periods indicated with current or planned staff additions (do not include any systems that you are currently designing or installing - See question 16). Also indicate your capability with expanded staff or by more extensive use of subcontractors:

	1981-1985		1986-1990		1991-1995	
	Present Staff	Expanded Staff	Present Staff	Expanded Staff	Present Staff	Expanded Staff
Systems Designed						
Number						
MW (Equivalent)						
Systems Installed						
Number						
MW (Equivalent)						

(14) Estimate the manpower increase required to meet the expanded staff capability information provided in (13) above:

Category	Man-years
Designers	________
Engineers	________
Crafts	________
Administrative	________

Do you anticipate any problems in meeting such an expanded staff requirement. If so, how would this modify the above "expanded staff" capability figures:

(15) Indicate the number and total equivalent MW of new systems you can install in the periods indicated, with both current staff and the expanded staff indicated in question 14, if the control efficiency stated in question 5 was reduced by 5 percent or by 10 percent.

Five percent reduction

	1981-1985		1986-1990		1991-1995	
	Present Staff	Expanded Staff	Present Staff	Expanded Staff	Present Staff	Expanded Staff
Systems Designed						
Number						
MW (Equivalent)						
Systems Installed						
Number						
MW (Equivalent)						

Ten percent reduction

	1981-1985		1986-1990		1991-1995	
	Present Staff	Expanded Staff	Present Staff	Expanded Staff	Present Staff	Expanded Staff
Systems Designed						
Number						
MW (Equivalent)						
Systems Installed						
Number						
MW (Equivalent)						

(16) Identify your present manpower distribution practices for the following phases of system design, fabrication and installation:

Item	Percent In-House Personnel	Percent Outside Labor[a]
Process Design		
Detailed Engineering Design		
Equipment Fabrication (list)		
System Installation		
Supervision		
Crafts		

[a] For example, subcontractors, job shops, licensee, etc.

……

FINANCIAL CONSIDERATIONS

(17) Estimate the costs of the following size particulate control systems operating at the efficiency stated in question 5 on both high ash (15%) and low ash (6%) applications:

Size (MW thermal)	Total Installed Costs ($/kW electrical)	Operating/Maintenance costs (Excludes Capital Charges) (mills/kWh).
2.9-7.3		
7.3-14.7		
14.7-29.3		
29.3-73.3		
>73.3		

(18) Describe the extent to which payment method(s) limit the number of system design/installation jobs your firm is willing to undertake (e.g., payment by company, only upon completion of specified project phases may limit numbers of systems undertaken because of cash flow considerations). Also describe the impact the various payment methods have on the time required to design and install systems:

(19) To what extent do available capital resources of the particulate control system manufacturers restrict the number of systems these suppliers are willing to design and the time required to install these systems:

(20) What corrective measures by government and industry do you think are necessary to alleviate financing related problems:

* * *

LIMITING ITEM ANALYSIS

(21) Identify the time required to design, install and start-up various size particulate control systems:

Size MW (thermal)	Time Required for Design and Installation		Time Required for Start-up	
	Average	Range	Average	Range
2.9-7.3	____ months	____ months to ____ months	____ months	____ months to ____ months
7.3-14.7	____ months	____ months to ____ months	____ months	____ months to ____ months
14.7-29.3	____ months	____ months to ____ months	____ months	____ months to ____ months
29.3-73.3	____ months	____ months to ____ months	____ months	____ months to ____ months
>73.3	____ months	____ months to ____ months	____ months	____ months to ____ months

(22) Estimate the time required to perform the various phases of system design and installation by phase. Also indicate whether the item listed is usually on the critical path and categorize the frequency with which each item leads to overall schedule delays:

	Lead Time (months)	Critical Path Item		Delay Frequency			External Supplier		
		yes	no	High	Average	Low	yes	no	name
Process Design	____								
Detailed Engineering Design	____								
Equipment Fabrication (list)	____								
*	____								
*	____								
*	____								
*	____								
*	____								
*	____								
*	____								
Equipment Installation	____								

(23) Identify the key items or factors leading to delay in the design, construction or start-up of particulate control systems:

(24) Identify corrective actions that can be taken by the utility industry, the government and others to overcome delay-related problems:

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APPENDIX C
SURVEY FORM SENT TO MANUFACTURERS OF SYSTEMS FOR NO_x FLUE GAS TREATMENT

NO_x Flue Gas Treatment

Manufacturer's name:

Address:

Name(s) of person(s) completing survey:

Telephone number(s) of above person(s):

oooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooooo

SYSTEM DESCRIPTION

(1) Type of system (attach additional sheets of description, if necessary):

(2) Wet or dry process:

(3) Applicability of system (delete as applicable):

New units: yes/no
Existing units: yes/no
Coal fired: yes/no
Oil: yes/no
Gas: yes/no

(4) Size range: from _____ MW to _____ MW

(5) Maximum NO_x removal efficiency:_________

(6) Will the system remove
particulates: yes/no, maximum efficiency: __________
SO_2 : yes/no, maximum efficiency: ___________

(7) Custom-designed systems or off-the-shelf:

(8) Own process or licensed:

(9) Regenerative or nonregenerative:

(10) Raw material considerations

Raw materials	Manufacturer	Specifications	Availability

(11) System byproducts

Complete either 11a or 11b.

11a - Regenerable systems

(i) What products can be produced

(ii) Is the regeneration facility supplied as part of the process or must the company make separate arrangements:

(iii) What is the demand for the recovered by-product:

(iv) Will you market the recovered products for company clients:

11b - Nonregenerable Systems

(i) Amount of waste products per lb of NO_x removed from the flue gas:

(ii) What form are the products in:

(iii) Is the waste potentially toxic or inert:

(iv) Can it be further treated:

(v) Can the system operate on a totally closed loop mode:

VENDOR GUARANTEES

(12) Indicate the type of guarantees you will provide and briefly describe their conditions and qualifications:

NO_x removal efficiency: yes/no. Terms:

Particulate removal efficiency: yes/no. Terms:

Predetermined installation cost: yes/no. Terms:

Performance (availability) guarantee: yes/no. Terms:

Other (describe): yes/no. Terms:

Comments (example of qualifications to guarantees):

OPERATING PERSONNEL REQUIREMENTS

(13) Identify the manpower required for effective operation of the following size FGT systems. Actual numbers will depend on specific company's operating practice:

	Men/shift					Total man-hours/year				
Position	2.9-7.3 MW	7.3-14.7 MW	14.7-29.3 MW	29.3-73.3 MW	>73.3 MW	2.9-7.3 MW	7.3-14.7 MW	14.7-29.3 MW	29.3-73.3 MW	>73.3 MW
Operators										
Maintenance										
Supervisor										

(14) Are you willing to contract for operation and maintenance of the system after installation: yes/no
If yes, comment on effects this will have on system guarantees:

VENDOR CAPABILITIES

(15) Indicate the number and total equivalent MW of new systems operating at the maximum efficiency stated in question 5, you can design and install in periods indicated with current or planned staff additions (do not include any systems that you are currently designing or installing - See question 18). Also indicate your capability with expanded staff or by more extensive use of subcontractors:

	1981-1985		1986-1990		1991-1995	
	Present Staff	Expanded Staff	Present Staff	Expanded Staff	Present Staff	Expanded Staff
Systems Designed						
Number						
MW (Equivalent)						
Systems Installed						
Number						
MW (Equivalent)						

(16) Estimate the manpower increase required to meet the expanded staff capability information provided in (15) above:

Category	Man-Years
Designers	
Engineers	
Crafts	
Administrative	

Do you anticipate any problems in meeting such an expanded staff requirement. If so, how would this modify the above "expanded staff" capability figures:

(17) Indicate the number and total equivalent MW of new systems you could install in the periods indicated, with both current staff and the expanded staff stated in question 16, if the control efficiency stated in question 5 was reduced by five percent and by 10 percent.

Five percent reduction

	1981-1985		1985-1990		1991-1995	
	Present Staff	Expanded Staff	Present Staff	Expanded Staff	Present Staff	Expanded Staff
Systems Designed						
Number						
MW (Equivalent)						
Systems Installed						
Number						
MW (Equivalent)						

Ten percent reduction

	1981-1985		1985-1990		1991-1995	
	Present Staff	Expanded Staff	Present Staff	Expanded Staff	Present Staff	Expanded Staff
Systems Designed						
Number						
MW (Equivalent)						
Systems Installed						
Number						
MW (Equivalent)						

(18) Identify your present manpower distribution practices for the following phases of system design, fabrication and installation:

Item	Percent In-House Personnel	Percent Outside Labor[a]
Process Design		
Detailed Engineering Design		
Equipment Fabrication		
Scrubber Vessels/Tanks		
Fan/Pumps		
Waste Treatment		
System Installation		
Supervision		
Crafts		

[a] For example, subcontractors, job shops, licensee, etc.

* * *

FINANCIAL CONSIDERATIONS

(19) Estimate the costs of the following size systems, operating at the efficiency stated in question 5 on both high nitrogen heavy oil or coal, and low nitrogen applications:

Size (MW thermal)	Total Installed Costs ($/kW electrical)	Operating/Maintenance costs (Excludes Capital Charges) (mills/kWh).
2.9-7.3		
7.3-14.7		
14.7-29.3		
29.3-73.3		
>73.3		

(20) Describe the extent to which payment method(s) limit the number of system design/installation jobs your firm is willing to undertake (e.g., payment by company, only upon completion of specified project phases may limit

number of systems undertaken because of cash flow considerations). Also describe the impact the various payment methods have on the time required to design and install the systems:

(21) To what extent do available capital resources of the control system manufacturers restrict the number of systems these suppliers are willing to design and the time required to install these systems:

(22) What corrective measures by government and industry do you think are necessary to alleviate financing related problems:

* * *

LIMITING ITEM ANALYSIS

(23) Identify the time required to design, install and start-up various size systems:

Size MW (thermal)	Time Required for Design and Installation		Time Required for Start-up	
	Average	Range	Average	Range
2.9-7.3	______ months	______ months to ______ months	______ months	______ months to ______ months
7.3-14.7	______ months	______ months to ______ months	______ months	______ months to ______ months
14.7-29.3	______ months	______ months to ______ months	______ months	______ months to ______ months
29.3-73.3	______ months	______ months to ______ months	______ months	______ months to ______ months
>73.3	______ months	______ months to ______ months	______ months	______ months to ______ months

(24) Estimate the time required to perform the various phases of system design and installation by phase. Also indicate whether the item listed is usually on the critical path and categorize the frequency with which each item leads to overall schedule delays:

	Lead Time (months)	Critical Path Item		Delay Frequency			External Supplier		
		yes	no	High	Average	Low	yes	no	name
Process Design	______								
Detailed Engineering Design	______								
Equipment Fabrication	______								
• Structural Steel	______								
• Scrubber Vessel/Tanks	______								
• Fans	______								
• Pumps	______								
• Instrumentation	______								
• Motors	______								
• Piping	______								
Equipment Installation	______								
Reactant Procurement (e.g., EDTA)	______								

(25) Identify the key items or factors leading to delay in the design, construction or start-up of systems:

(26) Identify corrective actions that can be taken by industry, the government and others to overcome delay related problems:

○○

APPENDIX D

SURVEY FORM SENT TO MANUFACTURERS OF COMBUSTION MODIFICATION SYSTEMS FOR NO_x CONTROL

Combustion Modifications for NO_x Control

Manufacturer's name:

Address:

Name(s) of person(s) completing survey:

Telephone number(s) of above person(s):

∘∘

SYSTEM DESCRIPTION

(1) Type of system (attach additional sheets of description, if necessary):

(2) Applicability of system (delete as applicable):

New units: yes/no
Existing units: yes/no
Coal fired: yes/no
Oil: yes/no
Gas: yes/no

(3) Size range: from _____ MW to _____ MW

(4) Maximum NO_x reduction efficiency:__________

(5) Custom-designed systems or off-the-shelf:

(6) Own process or licensed:

(7) Raw material considerations:

Raw materials	Manufacturer	Specifications	Availability

VENDOR GUARANTEES

(8) Indicate the type of guarantees you will provide and briefly describe their conditions and qualifications:

NO_X removal efficiency: yes/no. Terms:

Predetermined installation cost: yes/no. Terms:

Performance (availability) guarantee: yes/no. Terms:

Other (describe): yes/no. Terms:

Comments (example of qualifications to guarantees):

……

OPERATING PERSONNEL REQUIREMENTS

(9) Identify the manpower required for effective operation of the following size systems. Actual numbers will depend on specific company's operating practice:

	Men/shift					**Total man-hours/year**				
Position	**2.9-7.3 MW**	**7.3-14.7 MW**	**14.7-29.3 MW**	**29.3-73.3 MW**	**>73.3 MW**	**2.9-7.3 MW**	**7.3-14.7 MW**	**14.7-29.3 MW**	**29.3-73.3 MW**	**>73.3 MW**
Operators										
Maintenance										
Supervisor										

(10) Are you willing to contract for operation and maintenance of the system after installation: yes/no.
If yes, comment on effects this will have on system guarantees:

……

VENDOR CAPABILITIES

(11) Indicate the number and total equivalent MW of new systems, operating at the efficiency indicated in question 4, you can design and install in the periods indicated with current or planned staff additions (do not include any systems that you are currently designing or installing (see question 14). Also indicate your capability with expended staff or by more extensive use of subcontractors:

	1981-1985		1986-1990		1991-1995	
	Present Staff	Expanded Staff	Present Staff	Expanded Staff	Present Staff	Expanded Staff
Systems Designed						
Number						
MW (Equivalent)						
Systems Installed						
Number						
MW (Equivalent)						

(12) Estimate the manpower increase required to meet the expanded staff capability information provided in (11) above:

Category	Man-Years
Designers	________
Engineers	________
Crafts	________
Administrative	________

Do you anticipate any problems in meeting such an expanded staff requirement. If so, how would this modify the above "expanded staff" capability figures:

(13) Indicate the number and total equivalent MW of new systems you can design and install in the periods indicated with your current staff and the increased staff indicated in question 12, if the control efficiency indicated in question 4 was reduced by 5 percent and by 10 percent:

Five percent reduction

	1981-1985		1986-1990		1991-1995	
	Present Staff	Expanded Staff	Present Staff	Expanded Staff	Present Staff	Expanded Staff
Systems Designed						
Number						
MW (Equivalent)						
Systems Installed						
Number						
MW (Equivalent)						

Ten percent reduction

	1981-1985		1986-1990		1991-1995	
	Present Staff	Expanded Staff	Present Staff	Expanded Staff	Present Staff	Expanded Staff
Systems Designed						
Number						
MW (Equivalent)						
Systems Installed						
Number						
MW (Equivalent)						

(14) Identify your present manpower distribution practices for the following phases of system design, fabrication and installation:

Item	Percent In-House Personnel	Percent Outside Labor[a]
Process Design		
Detailed Engineering Design		
Equipment Fabrication (list)		
System Installation		
Supervision		
Crafts		

[a] For example, subcontractors, job shops, licensee, etc.

……

FINANCIAL CONSIDERATIONS

(15) Estimate the costs of the following size systems, operating at efficiency indicated in question 4:

Size (MW thermal)	Total Installed Costs ($/kW electrical)	Operating/Maintenance costs (Excludes Capital Charges) (mills/kWh).
2.9-7.3		
7.3-14.7		
14.7-29.3		
29.3-73.3		
>73.3		

(16) Describe the extent to which payment method(s) limit the number of system design/installation jobs your firm is willing to undertake (e.g., payment by utility, only upon completion of specified project phases may limit number of systems undertaken because of cash flow considerations). Also describe the impact the various payment methods have on the time required to design and install systems:

(17) To what extent do available capital resources of the control system manufacturers restrict the number of systems these suppliers are willing to design and the time required to install these systems:

(18) What corrective measures by government and industry do you think are necessary to alleviate financing related problems:

* * *

LIMITING ITEM ANALYSIS

(19) Identify the time required to design, install and start-up various size systems:

Size MW (thermal)	Time Required for Design and Installation		Time Required for Start-up	
	Average	Range	Average	Range
2.9-7.3	_____ months	_____ months to _____ months	_____ months	_____ months to _____ months
7.3-14.7	_____ months	_____ months to _____ months	_____ months	_____ months to _____ months
14.7-29.3	_____ months	_____ months to _____ months	_____ months	_____ months to _____ months
29.3-73.3	_____ months	_____ months to _____ months	_____ months	_____ months to _____ months
>73.3	_____ months	_____ months to _____ months	_____ months	_____ months to _____ months

(20) Estimate the time required to perform the various phases of system design and installation by phase. Also indicate whether the item listed is usually on the critical path and categorize the frequency with which each item leads to overall schedule delays:

	Lead Time (months)	Critical Path Item		Delay Frequency			External Supplier		
		yes	no	High	Average	Low	yes	no	name
Process Design	____								
Detailed Engineering Design	____								
Equipment Fabrication (list)	____								
•	____								
•	____								
•	____								
•	____								
•	____								
•	____								
•	____								
Equipment Installation	____								
Reactant Procurement (e.g., ammonia)	____								

(21) Identify the key items or factors leading to delay in the design, construction or start-up of systems:

(22) Identify corrective actions that can be taken by industry, the government and others to overcome delay-related problems:

* * *